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ABSTRACT

Significant curricular change extends into most other facets of schooling, including teaching, learning, and the school culture. This document reports findings of the Curriculum Reform Project, which conducted case studies of educational reforms in nine middle and senior high schools across the United States; prepared a cross-site analysis of the cases; and identified implications for policy, practice, and research. The focus of this 4-year research project has been curriculum reform, with specific attention to the three areas of science education, mathematics education, and high order thinking across the disciplines. The literature review found that proponents of higher order thinking favor the constructivist learning approach, which requires students to be active builders of their own knowledge and which requires a change in teaching strategies and teachers' roles. The cross-site analysis examined the nature of the curricular reforms, barriers to reforms, and essentials for attaining reform. The technical, political, and cultural dimensions of curricular reform efforts were examined. one conclusion is that reform is ongoing and requires a sufficient length of time. It also requires the provision of time for teachers, changed values and beliefs about the goals of instruction and means for fostering them, collaborative teacher learning, parent learning, new student roles and work, and a systemic view of reform. (Contains 177 references.) (LMI)

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Studies of Education Reform

STUDY OF CURRICULUM REFORM

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The Studies of Education Reform were initiated by the former Office of Research in OERI under the guiding hand of its Acting Director, Joseph C. Conaty, currently Director of OERI's National Institute on Student Achievement, Curriculum, and Assessment.

Studies of Education Reform

The 12 studies were commissioned by the Office of Educational Research and Improvement (OERI) in 1991 and were all completed by fall 1995. Each study comprises three volumes. Volume I contains a discussion of the study, case study summaries of the schools or school districts examined, and recommendations. Volume II contains detailed case studies. Volume III is a technical appendix explaining the study's methodology. OERI is publishing all Volumes I as a set. Titles in this series are:

Systemic Reform
Early Childhood Reform in Seven Communities
Education Reform and Students At Risk
Parent and Community Involvement in Education
The Uses of Time for Teaching and Learning
Systemic Reform in the Professionalism of Educators
Study of Curriculum Reform
Assessment of Student Performance
Assessment of School-Based Management
School Reform and Student Diversity
Technology and Education Reform
Study of School-to-Work Initiatives

The other two volumes for each study are available through the Education Resources Information Center (ERIC) system.

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PREFACE

As the educational reform efforts of the 1980s carried on into the 1990s, the Office of Educational Research and Improvement launched a program of research studies which addressed various facets of educational reform. The research reported here is the result of one of 12 such studies initiated by that Office in 1991.

The focus of this four-year research project has been curriculum reform, with specific attention to the three areas of science education, mathematics education, and higher order thinking across the disciplines.

Significant curriculum change is more than a curricular matter; it extends into most other facets of schooling, including teaching, learning and the culture of the school. Major change demands the attention of parents as well as the full range of school personnel.

As past research--and this study--shows, educational reform is an ongoing process and seemingly never complete. It requires a major commitment over a long period of time. This study tells this story in considerable detail, including the nature of various reforms, the barriers to reform encountered, and the means by which challenges were met and positive change achieved.

The report of this research is contained in three volumes: I. Findings and Conclusions, II. Case Studies, and III. Technical Appendix: Research Design and Methodology. This volume (I) contains summaries of the literature review, research questions, and case studies along with a complete presentation of the cross-site analysis of the cases and its implications for policy, practice and future research. The reader wishing to read the case studies in their entirety is referred to volume II.

This report is presented with the expectation that it will be helpful to others pursuing educational reform, whether they be policy-makers, practitioners, parents or researchers. With it go best wishes to all in the quest for improved education.

Ronald D. Anderson
Boulder, Colorado
June 1995

TABLE OF CONTENTS

PREFACE iii

ACKNOWLEDGMENTS vii

EXECUTIVE SUMMARY. 1

SUMMARY REVIEW OF LITERATURE 7

STUDY AIMS AND STUDY QUESTIONS 13

CASE STUDY SUMMARIES 17

- Fruitvale High School Mathematics 17
- River City High School Mathematics 19
- Mountainview High School Mathematics 21
- Fort Sheridan Middle School Science 24
- Fairview Middle School Science 26
- Westview High School Science 28
- Edison High School 30
- Oakgrove Middle School 32
- Rockview High School 34

CROSS-SITE ANALYSIS 37

ASSESSMENT OF THE OUTCOMES OF THE REFORMS 71

ASSESSMENT OF THE RESOURCES REQUIRED TO IMPLEMENT THE REFORMS 75

IMPLICATIONS FOR POLICY AND PRACTICE 79

IMPLICATIONS FOR NEEDED RESEARCH 83

BIBLIOGRAPHY 85

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A four-year project of this size requires the participation and support of many people. A debt of gratitude is owed to many people including those acknowledged below.

The first acknowledgement is to Mary Ann Varanka-Martin who served as associate director of the project during its first two years and returned to help at some key points in the project's final stages. She played the major role in organizing a national conference held in 1992, and managed much of the process of identifying study sites and gaining access to them.

Major investments of time were made by the staff researchers who conducted the case studies, including Kathleen Davis, Maurene D. Flory, Elizabeth Meador, Beverly Anderson Parsons, Stephanie Quate, Lew Romagnano, Erin Rosen and Joan M. Whitworth. Each person had a particular site to study, requiring several weeks on site in the assigned school and, of course, a long time "on the road." Analysis and writing was considerably more time-consuming. In addition to their impressive professional competence, their dedication and positive outlooks created a great collaborative working context.

In addition to conducting their individual case studies, Beverly Anderson Parsons and Lew Romagnano each provided leadership for one of the three components of the study--Beverly Anderson Parsons for thinking across the disciplines and Lew Romagnano for mathematics education. Their intellectual leadership was of great importance to the project. (Leadership for the science education component was provided by the project director, who also conducted one of the nine case studies.)

Hundreds of students, teachers, administrators, parents and other personnel connected with the schools we studied welcomed us, graciously shared with us their time and insights, and were patient with our quest for understanding. Memories of our time with people in these schools are pleasant indeed.

The many people who nominated educational reform sites for our consideration--and the personnel in these sites who provided further information for us--were important to our work. Their help is appreciated.

Our project's program officer at OERI, Judith Segal, played an influential role in shaping the project. Her reviews of our work were always insightful and helpful and she made the relationship between research group and funding agency positive and productive.

Our advisory group shared many valuable insights with us. Not being part of the working staff, however, they cannot be held responsible for what we did with their advice. They include:

Bill G. Aldridge, National Science Teachers Association
Susan R. Goldman, Vanderbilt University
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Ivette Torres, National Education Association

Margaret Eisenhart, a colleague at the University of Colorado, also served as an advisor to the project. Her insights and understanding of qualitative research made substantial contributions to our work.

Zaretta Hammond is to be commended for her editing skills and dedication to giving a diverse set of case studies some commonality in mode of presentation.

Other personnel at the University of Colorado, including secretaries Linda Webster and Bernice Moon, administrative assistants Patty MacDonald and Sue Middleton, Associate Dean Marc Swadener, and Dean Philip DiStefano each supported the project in important ways. Their support is most appreciated.

Many thanks to all.

Ronald D. Anderson
Project Director

EXECUTIVE SUMMARY

The core of the Curriculum Reform Project was conducting case studies of educational reforms in nine schools, preparing a cross-site analysis of the cases, and identifying the implications of this analysis for policy, practice, and research.

Review of Literature

The literature review conducted as part of the project highlighted important dimensions of the educational reforms sought in science, mathematics and higher order thinking across the disciplines. The literature identifies a number of common themes of the reformers and provides insights on the process of making changes in schools.

Common themes of the reformers. Learning to think is generally identified in the literature as an essential goal for *all* students, not simply those going on to higher education. It portrays this kind of thinking as 1) being complex, 2) not fully known in advance, 3) often yielding multiple solutions, 4) involving uncertainty, 5) requiring nuanced judgments, and 6) requiring considerable mental effort.

A constructivist approach to learning requires students to be active builders of their own knowledge, and not passive recipients of information. As active participants in their own learning, students construct their own meaning by negotiating that meaning with others, making connections with and modifying prior conceptions, and addressing content in a variety of contexts.

Constructivist learning among students requires a reconceptualization of teaching. Rather than viewing students as passive recipients of information, teachers must focus on helping students construct understanding of concepts for themselves. Instead of spending time memorizing material, filling in blanks on worksheets, and repeating large numbers of similar problems, students need to solve novel problems, integrate information, and create knowledge for themselves. The teacher's role is to foster this hard work on the part of the student.

A constructivist view of learning and teaching also requires changes in other components of schooling, namely, curriculum, assessment and policy. These aspects of constructivist learning and teaching are in various stages of development and research.

Barriers to change. Among the barriers to change are 1) the beliefs and values of everyone involved, 2) the lack of teacher preparation to teach constructively, 3) the need to reeducate students to their role in learning constructively, 4) the need for new instructional, curricular and assessment approaches along with high learning outcomes and expectations to support the teaching and learning changes, and 5) the tensions of instituting the new while operating in the old education system.

The process of change. The process by which change occurs varies greatly from one setting to another and from one time to another, although certain generalizations apply to successful change endeavors. First, a systemic outlook is essential. Second, positive and lasting change requires empowerment of teachers and an opportunity for them to develop their professional competency. Third, such fundamental and far-reaching changes imply significant changes in the culture of the schools.

Study Aims and Questions

Among the prominent research questions are ones pertaining both to the substance of the reforms and the means by which the reforms were put in place.

1. How are the sites defining their purposes and goals of reform with respect to students, teachers and the rest of the system?

2. What changes have occurred in the *content* of instruction?

3. What changes have occurred in the *means* of instruction, i.e., how are teachers fostering students' ability to construct desired learning outcomes?

4. What has been the impact on student learning and what can be inferred from positive results about various ways of teaching science, mathematics, and higher order thinking?

5. What are the mechanisms for change?

6. How do implementation efforts play out in classrooms; i.e. what happens in classrooms when teachers embrace the spirit of the reforms espoused by the various national groups?

7. How are sites developing high quality content that meets the needs of their full range of students?

8. How are sites developing teachers' abilities to use a constructivist way of teaching?

9. What are the dynamics of change as viewed from a teaching and learning perspective among (a) students, (b) teachers and (c) the rest of the system?

Fully understanding a complex and dynamic situation requires examining it from a variety of perspectives. The conceptual framework for this research is based on looking at a "slice" of the present (portions of one academic year) to understand (1) the past from which it came, (2) the

present (in terms of influences, results and dilemmas), and (3) the perceptions of future destinations held by the various people involved.

To understand more of how changes over time have and are occurring, it was necessary to examine the dynamics of the situation including the following. (1) What influences (e.g., pressures, supports or barriers) have affected these reforms? (2) What have been the results of these reforms? (3) What dilemmas have arisen for the various actors in these reform efforts?

A crucial aspect of the conceptual framework for the research was examining the results from a systemic perspective and considering all the influences in their totality and with their many interactions.

The Case Studies

The case studies were conducted in nine middle schools and senior high schools spread across the country. Selected on the basis of success in implementing currently advocated reforms, they included three mathematics departments, three science departments and three in which higher order thinking was being pursued across the disciplines. Each case study was conducted by a researcher using standard case study methodologies who spent 20 or more days on site.

Cross-Site Analysis

The cross-site analysis examined the nature of the reforms, barriers to the reforms, and essentials for attaining the reforms. These three foci were each examined within three dimensions: technical, political, and cultural. The results of the cross-site analysis are reflected in the implications presented below.

Assessment of the Outcomes of the Reforms

Generally, students at the sites under study performed as well on conventional standardized tests as students in traditional programs. New forms of assessment often were being developed to test for other outcomes not prominent in the goals of traditional instruction. Student excitement about learning and interest in the subject matter was evidenced by increased student enrollment in elective portions of the reformed programs.

Assessment of the Resources Required to Implement the Reforms

Although federal and state resources often were influential in initiating the reforms described in the case studies, the dollar amount expended for a given site was relatively small. By and large, local expenditures remained at normal levels, although resources often were reallocated to meet redefined needs.

Implications for Policy and Practice

1. The complex and fundamental reforms advocated by the reformers are not easy to establish, but they are appropriate and worthy of pursuit.

2. Time is a major dilemma for teachers in the reform context. While teachers find that the time pressures let up as they become more successful in implementing their reforms, it is apparent that the time demands of the reforms are a dilemma for teachers.

3. Expect the reform process to extend over a long period of time. The reforms cannot be hurried; they take years, not months.

4. Of central importance to the reforms are changed values and beliefs about the goals of instruction and the means of fostering this learning. To reform education in the full sense demands more than the acquisition of new teaching strategies and techniques.

5. Teacher learning is central to the process of reform, both in its own right and as a foundation for the required learning on the part of students and parents. The most important learning takes place in the context of collaborative work with other teachers, rather than in formal instructional settings.

6. Parent learning is an important part of the reform process, although the time it requires presents a significant challenge.

7. Students must be enabled to engage in new roles and perform new forms of student work. Establishing new student roles and student work probably is the true "bottom line" of reform.

8. Recognize that reform will hang in the balance for a long time. A critical breakdown in some aspect of the systemic support system that sustains the reforms could result in their abandonment at any point over an extended period of time.

9. At the same time, there is no going back on certain aspects of the reforms. While noting that reform will hang in the balance for a long time, one must also recognize that individual teachers who have successfully initiated these reforms in their own classes generally make convincing claims that their teaching has been changed permanently and they will never go back to the "old ways."

10. A systemic view is essential. It is obvious that these cases of successful reform are marked by attention to a multiplicity of factors in a manner that takes account of their interconnections. This multiplicity of factors is addressed simultaneously and in concert.

11. Reform is an ongoing process. Under the right conditions it can be expected to continue in schools, departments and individuals--probably at an uneven rate, but with a continuing overall movement toward reform.

Implications for Needed Research

Of the many research topics worthy of further research, a few have the potential of an especially strong effect; they are the ones deserving of additional research.

1. The results of this research strengthen the conviction that research in ordinary schools under everyday conditions is needed most. The process of making desired changes under ordinary school conditions is not the same as many of the "special" setting in which research is often conducted.

2. A closely related idea is to approach the research systemicly. The educational reforms being promoted today, the context in which these changes are being sought, and the various processes of fostering change are decidedly complex. Under these circumstances it is essential to approach the research systemicly.

3. Focus future research on student roles and student work. A critical finding of the cross-site analysis is that changes in the roles of students and in the nature of the work they do is at the heart of educational reform. A related finding of the research is that in the cases studied, a failure to bring about the desired level of change in this arena was almost universal. Thus, the highest priority for future research has to be given to how such changes can be attained.

4. Teacher Learning Needs Major Attention. Changes in students' roles and work will come about through the work of teachers in classrooms. Thus, the role of teachers needs major attention to understand better just how they can foster these student changes. The results of the cross-site analysis emphasize that teacher learning is central to educational reform and that (1) it apparently takes place most readily in collaborative work contexts, and (2) hinges upon changes in values and beliefs. Research is needed to understand more fully the collaboration that must be developed, especially in the day-to-day work context, but also through inservice education and through conferences and networks. More understanding is needed of learning organizations--in terms of both teachers and students--and how it is related to values and beliefs, both individually and collectively.

SUMMARY REVIEW OF LITERATURE

The diverse but interrelated dimensions of curriculum reform in science, mathematics and thinking across disciplines are captured in eight sections of a literature review developed early in the project (1992), and then published as a separate volume (Anderson et al, 1994). The principal themes and conclusions of the literature review are summarized here to provide the necessary perspective for the individual case studies, cross site analysis, and other elements of this total project.

This summary is organized around the three major themes that emerge from the literature review--common themes of the reformers, making the reforms happen, and implications of the research literature for the project.

Common Themes of the Reformers

Several themes are common among curriculum reform in science, mathematics and thinking across disciplines. These themes are:

- learning to think is an overall educational goal with particular significance in mathematics and science learning,

- a constructivist approach provides students with an active role in making meaning as well as learning,

- constructivist student learning requires the implementation of different teaching methods, and

- learning fundamentally important information at higher levels of understanding is preferable to encyclopedic learning of large quantities of information, or more succinctly, "Less is more."

Learning to think is generally identified in the literature as an essential goal for *all* students, not simply those going on to higher education. The research literature portrays this kind of thinking as 1) being complex, 2) not fully known in advance, 3) often yielding multiple solutions, 4) involving uncertainty, 5) requiring nuanced judgments and 6) requiring considerable mental effort. It also must be done in context; the subject matter of the school curriculum provides such a context, with science and mathematics as excellent examples.

A constructivist approach to learning requires student to be active builders of their own knowledge, and not passive recipients of information. As active participants in their own learning, students

- construct their own meaning by negotiating that meaning with their learning community,
- make connections with past personal understanding, modifying these prior conceptions if they are not accurate,
- build understandings that are part of their individual, personal conceptual framework, and
- address content in a variety of contexts as a means of developing full understanding.

Constructivist learning among students requires a reconceptualization of teaching. Rather than viewing students as passive recipients of information, teachers must focus on helping students construct understanding of concepts for themselves. Instead of spending time memorizing material, filling in blanks on worksheets, and repeating large numbers of similar problems, students need to solve novel problems, integrate information and create understanding for themselves. The teacher's role is to foster this hard work on the part of the student.

While the research indicates what such teaching involves, these findings are not as definitive as the findings pertaining to the learning itself; more is known about constructivist learning than constructivist teaching. In particular, this understanding of teaching is limited when considered in the context of classrooms having large numbers of students of diverse backgrounds and abilities.

A constructivist view of learning and teaching also requires changes in other components of schooling, namely, curriculum, assessment and policy. These aspects of constructivist learning and teaching are in various stages of development and research. With respect to curriculum, one theme is prominent in the literature--"Less is more." Some information is more important than other information in developing sophisticated understanding of science and mathematics. It is not just a matter of learning more, it is a matter of learning that which will help build the desired overall conceptual picture. Encyclopedic learning of large quantities of information can potentially interfere with this selective learning of that which is of fundamental importance--especially given the fact that some of these most important understandings are the most complex and require the most effort to learn. Effective learning requires focusing on the most important concepts and making the effort--on the part of the learner--required to build the necessary understanding. Greater selective attention to the most important conceptual understandings is the foundation of effective learning, thus the idea that "Less is more."

Significant curriculum reform is not possible without close attention to these basic principles of learning. As a result, current curriculum reform efforts such as Project 2061 of the American Association for the Advancement of Science (AAAS), the Scope, Sequence and Coordination (SS&C) Project of the National Science Teachers Association (NSTA), and the Standards of the National Council of Teachers of Mathematics (NCTM) all attend in substantial ways to

constructivist learning. Instead of presenting isolated facts, major attempts are made to focus on major themes of the subject matter and foster an integration of knowledge across disciplines.

Making the Reforms Happen

Desiring certain reforms and making them happen are very different matters. The case for the desired reforms presented above has strong support in the research literature. On the other hand, the means by which these reforms can be attained is not so certain. There are many barriers to change and the strategies for overcoming them are not fully understood. A major resource delineating both the characteristics and the systemic nature of educational change is Fullan's and Stiegelbauer's The New Meaning of Educational Change (1991).

Barriers to Change. Among the barriers to change are 1) the beliefs and values on the part of everyone involved, 2) the lack of teacher preparation to teach constructively, 3) the need to reeducate students to their role in learning constructively, 4) the need for new instructional, curricular and assessment materials and high learning outcomes and expectations to support the teaching and learning changes, and 5) the tensions of instituting the new while operating in the old education system.

Primary barriers to change are the operational and cultural belief and value systems and priorities of stakeholders including the teachers, administrators, students, the community, and reformers themselves. A certain amount of consensus is needed for reform efforts to be mobilized effectively over the years of time required. The more diverse these beliefs and values are, the more difficult the change. Even if reformers should agree on the matter of goals and the nature of learning and teaching, there is still the need for consensus regarding the means for reaching this new vision of education. Given the political context of reform efforts, it is clear that the lack of consensus among the public at large is a barrier to reform as well.

Teacher and administrator beliefs and values coupled with few models and a general lack of preparation to teach constructively present a second major barrier to change. Constructivist teaching requires changes in at least three areas of educational identity--subject matter, pedagogy, and personal. As a coach, teachers must monitor both process and product through changes in classroom management, teaching strategies, and assessments.

Similarly the new expectations of students are a barrier. Many students, often those who are most successful in the current system, resist changing from a predictable process in which they know how to succeed to one which fosters intellectual development in a context of some uncertainty, problems with multiple solutions and a lack of specific directions as to what to do. Students may be joined in their resistance by parents who understand the existing system but also find the new expectations confusing and demanding.

Even if there is an adequate consensus vision of what education should be on the part of everyone involved, change is not assured. Change is not easy; in particular, changes in roles of people are difficult. It is not easy for teachers to learn the new roles required of those who want to foster constructivist learning among students. It is not easy for students to overcome passivity and learn the needed role as a responsible and proactive learner.

Another barrier to reform is the lack of compatible instructional materials. None of the major science and mathematics education reform efforts of the AAAS, NSTA, or NCTM have produced curriculum materials for use with students. Although there is a limited patchwork of such materials--some developed by recent National Science Foundation (NSF) funded projects--none of the nationally recognized efforts of AAAS, NSTA, and NCTM as yet have produced comprehensive curriculum models and related teaching materials for students. While all students have been targeted for participation in the new approaches to learning, the levels of outcomes and expectations of students have not yet been operationally delineated.

All of the barriers described above exist within powerful institutional and cultural constraints. While the problems of bureaucracies, limited budgets, assessment practices, and rigid regulations are well recognized, the cultural constraints are at least as powerful, but often less visible. The commonly accepted values, beliefs and practices of the society found within a given school or community form a common culture which typically is a powerful constraint to change and generates tension during the reform process.

There are many barriers to educational reform; change clearly is difficult. It requires resources, commitment, knowledge and skills. Moreover, success depends upon applying them in the correct setting with appropriate timing. It is this approach to change which needs further attention.

Process of Change. The process by which change occurs varies greatly from one setting to another and from one time to another. Although certain generalizations appear to apply to successful change endeavors, there is no particular set of processes (plural) to apply to ensure success. The overall process (singular) varies greatly but there are some important understandings that seem important to success--a systemic outlook, the empowerment of teachers and the development of a change culture in the school.

First, a systemic outlook is essential. All efforts to introduce new instructional approaches, new curriculum materials or instructional goals demand such actions as inservice education for teachers, discussions with parents to develop consensus on goals and new directions and leadership from administrators. Change requires attention to the subculture of students, schools, and communities. None of these actions by itself is sufficient. All of them together may not work if initiated without consideration for how they interact with each other. A systemic thinking approach to change accounts for the synergy of the individual perspectives--institutional, sociocultural, psychological, organizational, philosophical, political and subject matter--which all

play a role in the initiation, implementation and continuation of change (Anderson, 1992). Actions taken at the national, state, district, school, and classroom levels, for example can interact to support change in a common direction, or they can counteract each other in such a manner that change is defeated. And even though actions taken are complementary, there is the possibility that the omission of some particular action or actions could stall what would otherwise be a successful reform effort. A vision of what should be must be combined with a systemic process of working toward that vision.

Second, positive and lasting change requires empowerment of teachers and an opportunity for them to develop their professional competency. Constructivist learning demands constructivist teaching. Such substantial change demands that teachers be empowered to examine and reshape their professional identity and develop their professional competencies. In effect, teachers need to construct new understandings of their role and develop the ability to incorporate these new understandings into their actions as teachers and to become reflective learners themselves. These new changes need to be reaffirmed by the development and use of constructivist assessments to support the changes in materials and teacher development.

Third, such fundamental and far-reaching changes imply significant changes in the culture of the schools. It means new roles for teachers, students, parents, and administrators. More collaboration among teachers and new responsibilities, for example, may emerge as important elements in this changed culture. Such changes demand a systemic outlook that causes individuals to reassess values and beliefs pertaining to education.

There are many strategies and processes which research (Fullan and Stiegelbauer, 1991) indicates are part of such a systemic approach. They are important to successful reform. This research has many facets and deserves close consideration. This consideration, however, must take place within the framework of systems thinking and an organizational context that is changing (Senge, 1990).

The Literature Review Process

Because this literature is very extensive and several facets previously have been reviewed in a competent manner, the first step throughout was to consult other reviews. As a result, reference often has been made to such reviews as an overall picture was painted of what research has to say about curriculum reform in the areas under consideration. Where such reviews had not been conducted, or were somewhat dated, and where connecting information was needed, the research literature was searched following standard procedures. For handy reference, all items in the literature review appear in the bibliography at the end of this volume.

STUDY AIMS AND STUDY QUESTIONS

A research plan was developed as the foundation for a set of nine case studies--three each in mathematics, science and thinking across the disciplines--to be conducted during the 1992-93 and 1993-94 school years. The culmination of a year of preparation, the plan reflected insights gained through prior work of the Curriculum Reform Project, including an extensive literature review, a set of commissioned papers and a national conference of practitioners and policymakers. It includes a set of research questions and a conceptual framework having multiple perspectives for viewing the questions and subsequent data collection.

The Research Questions

Among the prominent research questions are ones pertaining both to the substance of the reforms and the means by which the reforms were put in place. The substance of the reforms includes attention to both the content of the curriculum and the instruction by which students acquire it. The means by which the reforms are put in place includes particular attention to systems thinking and the overall patterns of reform activities.

The substance of reform. The following questions are among those addressed with respect to the curriculum reforms themselves.

1. How are the sites defining their purposes and goals of reform with respect to students, teachers and the rest of the system?

2. What changes have occurred in the *content* of instruction?

3. What changes have occurred in the *means* of instruction, i.e., how are teachers fostering students' ability to construct desired learning outcomes?

4. What has been the impact on student learning and what can be inferred from positive results about various ways of teaching science, mathematics, and higher order thinking?

5. How "deep" are the changes; i.e, have the beliefs of students, parents and teachers changed?

6. To what extent and how is the *learning* and *teaching* of thinking skills being transferred across disciplines?

The means of reform. Attention also is directed to how people got to where they are. This investigation includes looking for patterns of support throughout the system and examining how people monitor their progress toward desired goals.

1. What are the mechanisms for change?

2. How do implementation efforts play out in classrooms; i.e. what happens in classrooms when teachers embrace the spirit of the reforms espoused by the various national groups?

3. How are sites developing high quality content that meets the needs of their full range of students?

4. How are sites developing teachers' abilities to use a constructivist way of teaching?

5. What are the dynamics of change as viewed from a teaching and learning perspective among (a) students, (b) teachers and (c) the rest of the system?

6. How are sites working out the trade-offs related to financial and expertise resources?

7. To what extent has the process of reform been top-down, bottom-up, or some combination of the two?

8. What are the means of system support? To what extent and in what ways are the system support strategies congruent with a constructivist view of teaching and learning?

9. To what extent does the approach to change at the sites reflect systems thinking?

Conceptual Framework

Fully understanding a complex and dynamic situation requires examining it from a variety of perspectives. Looking at it from a variety of vantage points provides a fullness of understanding not possible when seen during a limited time span, through the eyes of only selected categories of participants, or from the standpoint of selected interactions within the total dynamic setting.

Many perspectives are built into the conceptual framework to ensure that field observations and interviews acquire data needed for a wide range of analyses. Coherent portrayals of the situation in each school later will require a limited number of analyses, but at the beginning a fairly broad set of perspectives is demanded, as described below.

Time perspective. The conceptual framework for this research is based on looking at a "slice" of the present (portions of one academic year) to understand (1) the past from which it came, (2) the present (in terms of influences, results and dilemmas), and (3) the perceptions of future destinations held by the various people involved. As a result the research questions stated above must be expanded upon to give a form such as the following.

- What are the *past* patterns of school practice from which the current practices emerged?

- What is the nature of *current* school practice?

- What is the *future* which the various actors envision as their intended destination?

Influences, results and dilemmas. To understand more of how changes over time have and are occurring, it is necessary to examine the dynamics of the situation including the following.

- What influences (e.g., pressures, supports or barriers) have affected these reforms?

- What have been the results of these reforms?

- What dilemmas have arisen for the various actors in these reform efforts?

Multiple dimensions. These questions about influences, results and dilemmas encompass at least the following four dimensions:

- *Personal*: influences based in the knowledge and beliefs of the individual actors involved in the reform effort as these beliefs and knowledge relate to such matters as the discipline, teaching, learning, school and students.

- *Interactional*: influences based in the interactions of people in classrooms or other settings.

- *Contextual*: influences arising in the social, cultural, structural, organizational, political, or historical context.

- *Historical*: influences arising from past events and their resultant structures, patterns of interaction, and convictions of people.

Interest group perspectives. What are the perspectives of the following at each site and how do they compare: students, teachers, administrators, policymakers, and parents? How does the reform as defined at each site map onto reform ideas as defined by (1) professional groups at all levels, and (2) the public in general?

Systems thinking. How can a systems approach to analyzing these reforms help in understanding the changes?

Subject-matter perspective. Because of the importance of subject-matter considerations within this research, the research questions must be explored from both discipline and non-discipline specific perspectives.

Critical components. The following guides to observation, questioning and analysis are used.

- *Student goals and expectations* as exhibited in intended and actual learning outcomes.

- *Teacher professionalism* as reflected in professional development activities and participation in professional work such as curriculum development.

- *Vision* as indicated by changes in school curricula or pedagogical practices, school routines or daily operations, and statements of vision.

- *Curriculum, instruction and assessment design* including the degree of complementarity of these three.

- *Changing roles* of students, teachers, administrators and parents, with attention to their responsibilities and the interrelationships of these roles.

- *Resource allocation*, including both financial allocations and the expenditure of professional time.

- *Means of expanding the reform* to additional individuals and groups, or portions of the curriculum.

CASE STUDY SUMMARIES

CASE STUDY OF FRUITVALE HIGH SCHOOL MATH DEPARTMENT

Elizabeth Meador

In some sense, the history of reform at Fruitvale High School, one of two high schools in a city of almost 200,000, parallels the reform of math education which has been occurring over the past 20 years at a national level. In the 1970's, a confluence of ideas produced an impetus for the reform of math education. The "new math era" of the 1960's was seen as a failure as educators saw test scores fall and conceptual understanding among students falter. The pendulum began to swing towards a "back to the basics" movement in the 1970's. This "back to the basics" movement then led to the current focus in mathematics education on conceptual understanding, which was seen as a weak point in the "back to the basics" movement. This pull between the "back to the basics" emphasis on factual knowledge and the current emphasis on conceptual knowledge is an unresolved struggle in the mathematics department at Fruitvale.

Some of the questions pervading the mathematics community at large, as well as the Fruitvale mathematics department are: How much and what kind of basic content knowledge must a student have? What is the place of computational expertise vs. conceptual understanding? How much rote knowledge must students possess in order to be successful in their conceptual understanding? What is the place of technology in the mathematics classroom? What does a foundation in mathematics look like? What kinds of skills must students have before they can solve problems in context?

These questions have been in the minds of a select group of Fruitvale mathematics teachers since the mid-1980's. Two Fruitvale teachers attended national leadership institutes, one in 1986 and one in 1988. Through these activities, these teachers began working with math educators from around the nation, and brought new ideas back to Fruitvale. They began developing courses which, through the use of technology, were designed to enhance students' understanding of mathematics. A group of three teachers also developed courses which have been successful in restructuring the mathematics learning experience through strategies such as team work, discovery learning, and the use of content embedded in context.

To a high degree, the impetus for mathematics curriculum reform at Fruitvale has come from the initiative and experience of three teachers involved in the activities described above, all of whom saw the need to redefine the body of knowledge called mathematics. In general, their passion has caught on with other teachers in the department, and the tone within the department is one of willingness to take risks, write proposals for funding, try new materials, and work to involve students in mathematics.

Yet not all teachers share the same reformed-oriented philosophical viewpoint of the goals and basics for mathematics. Also, some of the teachers in the department have begun to resist changing the curriculum because they do not feel that they are a part of the decision making process around those changes. These philosophical and power struggle issues are two of the sticking points in the progression of curriculum reform at Fruitvale.

Another difficulty in the process of curriculum reform is that the new materials and philosophies tend to shake up the traditional roles of teachers and students. Those teachers who believe that mathematics should be done differently are confronted with uncertainty about how to implement their vision of the reformed mathematics classroom. The new materials tend to demand that students construct their own knowledge and be active rather than passive learners, as well as for teachers to be the facilitators of the students' active learning. However, the teachers are trained to be the deliverers of knowledge and they employ such strategies as lecturing to get information across to their students. The new materials render strategies such as lecturing inappropriate, and yet teachers are uncertain as to what other strategies to use. They want to put the students in an active role, but they do not know how to do this. As a result, the teachers' visions for reform in mathematics is impeded by their lack of training in new, facilitator-oriented pedagogical techniques.

Another challenge to the reform at Fruitvale is that while curriculum materials are being revised, assessment practices are not. Some teachers continue to use unit and chapter examinations as their form of assessment. Other teachers see assessment as an ongoing process and utilize a variety of methods to assess students' skills and knowledge. But all teachers feel that the most important assessment measure is that which is provided by the SAT, as the community wants students to be successful on this standardized test. As yet, there has been little success in bringing the community on board in the efforts toward mathematics reform.

In addition, at both the school and district level, administrative support for mathematics reform has grown less cohesive over the past few years. While there is interest and perhaps even vision on the part of the school and district administration for reform in mathematics, there is a lack of agreement in how to bring the reform into being.

In all, the greatest impediments to reform at Fruitvale are the fragmented nature of the reform efforts in the context of the district, and the lack of a cohesive, school-wide or community-wide vision regarding the direction of the reform. In order for the reform to go forward at this site, the discourse regarding what mathematical understanding is and what body of knowledge kids should have when they finish high school must continue. The process is ongoing as these educators strive to change the tradition of high school mathematics.

CASE STUDY OF RIVER CITY HIGH SCHOOL PROJECT CLASSES

Maurene D. Flory

River City High School (RCHS), a traditional public high school, is one of several state sites for the implementation of ideas from a National Science Foundation (NSF) State Systemic Initiative Program in mathematics, encompassing the mathematical and pedagogical tenets of the National Council of Teachers of Mathematics (NCTM) Curriculum and Evaluation Standards for School Mathematics (1989). Specifically, this project espoused combining traditional (algebra, geometry, trigonometry, and calculus) and non-traditional (probability and statistics) mathematics topics with the use of technology (graphing calculators and computers) and multiple teaching techniques in a constructivist mode to solve mathematical problems based on applied contexts. Corresponding curriculum materials were written by a variety of people, most of whom are secondary school mathematics or science teachers, under the guidance of university professors and college educators, to replace traditional mathematics courses at the high school level. This restructuring of mathematics is designed to make mathematics more accessible and more widely used by students.

This case is not a study of this state-wide program but a study of one school that chose to use its ideas and materials in mathematics. To date, RCHS offers its students a choice between the new and traditional mathematics for their first two mathematics courses to meet state graduation requirements and begin college preparation.

RCHS mathematics teachers have a demonstrated culture of sharing their time, energy, material resources and enjoyment of mathematics with each other and seek opportunities to expand their pedagogical and mathematical knowledge. It has resulted in success in training students for academic mathematics experiences. The prevailing ethos in the department is one of caring about teaching the students and the mathematics. They see the new approach as an attempt to expose more students to mathematics and to assist these students in gaining more mathematics skill and knowledge. Some of these teachers were among the first trained in the new approach, having the most classroom experience with the curriculum, while others are just now coming on board. RCHS teachers make use of both the initial inservice training as well as the ongoing training that is available.

The teachers of the new classes also teach some traditional mathematics classes. For their new classes the teachers share two especially equipped rooms which are outfitted with eight long tables having seating for eight students per table and one computer per table. They also share the class set of graphing calculators and manipulatives.

Several elements of the new approach are problematic for the teachers. These elements include the small group, cooperative learning techniques, the reduced emphasis on drill, limited experience and/or poor directions for the use of the integrated technologies, presentation of non-

mathematical skills and knowledge necessary to present the context of the real-world problems, and new methods of assessment. Despite these difficulties, which in general the teachers solve through collegial interactions, teachers carry some of the new techniques, especially the questioning techniques, into their regular math classes. Beyond the classroom concerns, these teachers have questions about the cost/benefit relationship of the resource intensive new classes to the traditional math classes, the amount of mathematics content taught in the new classes, and a need to be more directive in their teaching to make certain that their students know the basics.

The student body at RCHS is mostly white, with the largest minority being American Indian. The students who enroll in the new courses come overwhelmingly from the lower-economic status feeder school. A third of these students come from homes whose parents are employed in a business that requires frequent relocation. While taking the new classes for a variety of reasons, a quarter of them said that they now are a better mathematics student than they have been in the past, or than they think they would be in a regular mathematics class, and most believe it is more appropriate for them than a traditional mathematics class.

The students categorize their new classes as easier than a traditional class, meaning that the mathematics is less complicated, less number oriented, less repetitive and easier to understand, but not less or easier in the scope of the work. The students cite interpersonal dynamics (both teacher-student and student-student), use of technology, and formats for material presentation as key elements of the difference.

Student responsibility in the new classes is greater, as are the consequences for not participating. Students are responsible not only for their homework but also for participation in their cooperative group, by explaining concepts to other group members, by not "sliding" by or relying heavily on other group members, and by being pro-active in seeking the help of their group when they need it. Assignments are less frequent, less repetitive, more explanatory, and more thoughtful, thus not completing homework assignments for these classes students can affect both their individual progress, and the progress of their small group and/or whole class.

Change here necessitates continuation and clarification of several aspects of the new approaches. One point of growth and struggle at RCHS is the need for teachers and students to continue their participation in new experiences and acquisition of new skills and knowledge. The process of developing consensus must continue, especially while clarity about the role of the new classes within the culture of the mathematics department is being considered. An environment for continued teacher learning is needed for the areas of the new curriculum (e.g. the group work, the technology, the assessments) which still present challenges to both teachers and students. If these new classes are to succeed, their goals must be made clear not only about which students they serve but also about the alignment of the knowledge generated in these classes with college course knowledge. More administrative involvement is necessary. A presence in new curriculum classrooms as well as a sensitivity to resource needs, primarily staff development are critical.

CASE STUDY OF MOUNTAINVIEW HIGH SCHOOL MATHEMATICS DEPARTMENT

Lewis Romagnano

Mountainview High School, with a student body of about 1,700 students, graduated its first senior class at the end of the 1992-93 school year. A year before Mountainview opened, the district convened a "cadre" of teachers, administrators, and parents to plan the new school's academic program. Carol Jennings had been teaching in the district for years and was a well-known figure among mathematics teachers throughout the district and across the state. Her reputation for leadership and innovation-in her classes as well as at the state and national levels-made her a natural choice to head the new mathematics department.

Carol and the other members of the school's leadership team chose the "Five I's"-Interactive, Integrated, Interdisciplinary, Individualized, and International-as themes to guide each subject area's curriculum. In the mathematics curriculum, the new school was to have a program that would give all of its students access to the mathematics knowledge they would need to meet the district's developing mathematics proficiency list. The program was to be integrated, blending the traditionally separated disciplines of algebra and geometry, along with less traditional disciplines like probability, data analysis, and statistics. It would ask students to solve meaningful and realistic problems and tackle extended projects. It would group students heterogeneously, rather than track students based on prior achievement or some measure of "ability." It would stress cooperative learning and use of technology. And, sensibly, it would be based on curriculum materials already written.

A set of innovative integrated curriculum materials was chosen for the seventh and eighth grades. For the high school, they chose a three-year, problem-centered, "interactive" curriculum that was being written and implemented in another state. It became known as "INT," integrates mathematics "strands," links content to real-world applications, and does so in a classroom setting that encourages cooperative group work and use of technology, problem solving, and emphasis on written and oral communication. Teachers and students described the difference of the INT content as: more student-oriented than teacher-oriented; more integrated with regard to topics; more challenging than traditional math classes; more demanding in terms of writing; and more demanding in terms of thinking.

At the same time, an "alternate sequence" of Algebra I, Geometry, Algebra II/Trigonometry, Pre Calculus, and AP Calculus was offered at Mountainview. Some of the most innovative texts available were used in these classes, and many of the mathematical problems from the INT courses made their way into the "traditional classes."

The role of teachers in the INT I classes were similar in several ways. The teachers would assume the familiar position at the front of the room, speaking while students listened, but they

would do so for only about five minutes. Then the teachers moved physically and pedagogically away from the center, joining the students as mathematical sense-makers and assuming the roles of problem poser, discussion participant, and observer.

The students played a central role in the INT classes. The focus in these classes was on the students' efforts, individually and in small groups, to make sense out of problem situations and their classmates' struggles to understand these efforts. Making presentations to their peers, the students assumed prominent positions as leaders of, and participants in, discussions with each other and with the teacher. A good portion of their time was spent working in groups of about four students. During this time, the students either reviewed homework or wrestled with new problems.

Pushed together in threes and fours, students' desks provided large work surfaces as they sit facing each other. In addition, none of the students had textbooks; rather, they referred to their three-ring binders and folders, which contained packets of copied materials. In their groups, the students worked through problems from the packets. When students had questions, they would either talk to the teacher individually or pose the questions before the entire class, generating class discussion.

For assessment measures, students were assigned daily homework, worked on "problems of the week" (although a bit less frequently than once per week), were given assessments (some of which are included in the packets of materials), and took "matrix finals" each semester. Additionally, teachers evaluated the extent of student's participation to class discussions and group work, attention to others, and how often they presented problems to the group. Students were also given a number of opportunities for self-assessments.

The development of alternatives to traditional assessment schemes raised several important issues at Mountainview. The first was the degree to which each component was actually used by individual teachers. Some teachers did not implement all of the assessments consistently, if at all. Additionally, tensions arose because the alternative assessment schemes were perceived by some students, parents, and teachers as being "subjective" and therefore less fair.

The 14 Mountainview mathematics teachers were grouped into teams made up of those who taught the various sections of each course. Team planning sessions for each course were a regular part of these teachers' already crowded schedules. In their meetings, the teachers discussed pedagogical issues such as how to determine the appropriate size of groups; how to incorporate the use of graphing calculators in subsequent problems for which students will use the same graph-interpret-predict approach; what sequence teachers will follow for the next few problems in the unit; and how to assess student work.

Despite these structures for discussions between teachers, there did exist breakdowns in communication between teachers in the department who were deeply divided on fundamental issues of mathematics curriculum and pedagogy.

CASE STUDY OF FORT SHERIDAN MIDDLE SCHOOL SCIENCE PROGRAM

Kathleen S. Davis

As part of a major district wide reform--from junior high to middle schools--Fort Sheridan Middle School (FSMS) first field tested and then adopted the materials of a National Science Foundation (NSF) funded science curriculum development project at the instigation of a district administrator. Through this innovative science program, both the curriculum developers and the school district in this study sought to increase the participation and success of all students in science classes, including traditionally under-represented populations (i.e. minorities and girls). Teachers and administrators perceived this curriculum as a vehicle with which they could accomplish their goals of inclusion and curricular change.

The program seeks to 1) develop middle school students' understanding of basic concepts and skills related to science and technology, 2) increase the participation and success of under-represented populations (i.e. girls and minorities) in science classes, 3) improve students' understanding of how science and technology relate to their everyday lives, and 4) promote the development of higher-order thinking skills. To achieve these goals, the curriculum integrates earth, life and physical sciences through units that are developed around conceptual themes that are repeated, built upon and linked together throughout the curriculum. Additionally, students investigate the important elements of technology, such as the design process. The program utilizes an instructional model based on constructivist learning theory in which students reflect on prior knowledge, participate in hands-on investigations and use cooperative learning strategies to explore key concepts, solve problems, and construct new knowledge.

FSMS is located adjacent to a small city on a military base in the heart of an agricultural region. The school serves nearly 700 students, who are 48% white, 35% African-American, 9% Hispanic, 4% Asian or Pacific Islander and 1% American Indian or Alaskan Native. Nearly 92% of these children's parents are military personnel, primarily enlisted personnel, and nearly 88% of the students live on the military base. The school is part of a larger district with very similar demographics. The faculty members come primarily from agricultural backgrounds and have lived in the region for much of their lives. Some of the school's educators have spouses who are in the military.

Over the last four years, many pathways have been constructed at FSMS to facilitate the change to this reform curriculum. Concurrently, obstacles have also emerged.

Teacher knowledge, experiences and beliefs greatly impact what takes place within the classroom. Participants in this reform believe it is vital that teachers believe in and understand the reform curriculum and its instructional strategies in order to teach it successfully. Teachers, though, came to this reform with varying degrees of knowledge about and experience with the

philosophy and instructional approaches of the curriculum. For some teachers the reform process was an opportunity to implement new approaches and strategies that reflected where they were and where they wanted to go. For other teachers, the reform was very different from what they normally did in their classrooms. These teachers felt they had been teaching successfully and saw little need to make changes in their teaching philosophy.

Teacher learning was key to the process of implementing this science reform curriculum which affects the daily science instruction in the classroom. Regular and frequent staff development institutes, in-service workshops and the creation of a sixth grade science team provided critical opportunities for interactions with colleagues and outside support personnel which contributed to teacher learning. The support of university site-coordinators and staff, program developers and administrators as well as the use of interactive forums diminished after the field test. This loss curtailed further development of teacher knowledge and of a common vision among teachers. It also failed to address the needs of teachers who, late in the reform process, came to question and struggle with their long-held, traditional ideas; they needed support. In addition, the retention of old decision-making structures within the district and school conflicted with this reform and seriously influenced its further development and that of teacher learning.

The field test process was difficult and frustrating. It limited the incorporation of teachers' prior knowledge and impacted teacher acquisition of new instructional strategies. Importantly, teachers were viewed as professionals and served as "co-developers" and provided the program developers with feedback that was incorporated into future versions of the field test materials.

As FSMS field-tested their new curriculum, the state established science standards that paralleled the features and goals of the reform. When creating new state assessments, state leaders, though, hesitated to move beyond objective testing. FSMS played an important role in the creation of new, authentic, state assessments that support the school's four-year endeavor for change.

This program requires students to think, questions, compare, contrast and connect ideas and information as they work in cooperative teams. They must make observations, draw conclusions, make predictions, design ways to test ideas and carry out their testing methods. Due to their new and active roles, the responsibility for learning shifts from the teacher to the student. Some students increasingly assume the designated roles and responsibilities of the cooperative team; they become more responsible for their learning. However, some teachers struggle with their new roles as coach and facilitator; they take on student cooperative team roles and responsibilities and, as a result, students assume them less and are less responsible for their own learning.

CASE STUDY OF FAIRVIEW MIDDLE SCHOOL SCIENCE DEPARTMENT

Joan M. Whitworth

Fairview Middle School implemented a Scope, Sequence and Coordination (SS&C) curriculum, called State Project for Reform in Science Education (SPRSE), over a period of three years beginning in the fall of 1991, first with the sixth grade curriculum and adding one grade level each succeeding year. The implementation was a joint effort between seven schools and two near-by universities with National Science Foundation funding for staff development and technical support. The implementation process included inservice education on new approaches to teaching science, writing a new curriculum, pilot testing the material, rewriting, and evaluating the reform. Site-based management within the district provided Fairview with the opportunity to pursue this science reform independent of other schools in its district. The costs for implementing the SS&C program were borne primarily by the local university with Fairview paying for release time, substitute teachers, and lodging for participants to attend meetings and training sessions.

Fairview Middle School is located in a little town at the edge of a mid-sized city, with students from a low income area of the city, a middle income suburb, and the original rural community surrounding the little town. Federally mandated integration has created a 50% minority student population within the school.

Fairview Middle School is organized into interdisciplinary, grade level teacher teams. The seventh grade science teachers, due to their physical proximity in the building work together, but in general the science teachers more closely identify with their interdisciplinary team members. Major differences identified with teaching the reform center around not having a textbook, student and teacher questioning strategies, and student group work and its social interaction. Increased longevity within the project correlates with enthusiasm for it. Experienced project teachers recognize that teaching the project, discussing difficulties with colleagues locally and state-wide, and reteaching it a second year were critical to developing a commitment to the project. Teachers new to the reform project are uncomfortable with many of the changes.

Fairview teachers see the benefits of the reform to be 1) improved student interest and enjoyment of science, 2) improved student self-esteem and social skills, 3) increased student understanding of material, 4) improved relations, teacher to student and teacher to teacher, 5) success for *all* students in science, and 6) increased teacher learning. Their major concern beyond the usually difficulties of reform is the amount of time involved in the preparation and planning for teaching in the reformed curriculum.

Viewing the reform from the perspective of six key areas--goals, content, teacher role, student role, student work and assessment--the reform meets only some of the demands of reform

efforts. The goals of "less is more" and thematic, real-life science are met in the science content which stresses a depth of understanding of science concepts and the connections existing among science disciplines and between science and life experiences outside the classroom. While the reform involves more group activities for students, both the student and teacher roles remain virtually unchanged. Some teachers do assume a role of coach during cooperative learning activities, but for students it is primarily a format change and not a change in their role or response.

Student work is more creative and diverse, encouraging student-designed experiments, student-generated science games, journal writing, poster designing and mapping. By teacher admission, student assessment lags behind other parts of the reform and is compounded by a district-wide traditional percentage grading system. New tests more compatible with the reform will not be available for at least two years.

Critical to this reform is teacher inservice education, which is aimed at demonstrating the operation of the reform at the classroom level and impacting teacher beliefs about practice. The inservice education includes a two-week summer institute and follow-up procedures. Without continued inservice education, and continued university support, the reform may be difficult to sustain. Additional outside funding is being sought to sustain and expand the program.

COORDINATED SCIENCE AT WESTVIEW HIGH SCHOOL

Ronald D. Anderson

The Coordinated Science program was introduced to the Westview High School science department in 1988 by Karl Tozer, the science department chair. Tozer had caught wind of changes in science education being addressed through the National Science Teachers Association's Scope, Sequence, and Coordination project and California's new Science Curriculum Framework. By the 1992-93 school year, 6 of the 7 science teachers at Westview High School taught Coordinated Science, which includes biology, chemistry, physics, and earth science. The Westview science teachers were attempting to

- Teach students to see connections between different disciplines of science.
- Teach students to see connections between concepts and the "real world."
- Teach students to think on their own, ask questions, and be problem solvers.
- Generate students' interest in science and inspire them to take additional science courses.

While the Coordinated Science Program is designed for all students, it is also said to be taught "at a college prep level." Both the content coverage and the depth in which it was pursued are intended to meet the needs of students who will be attending college. To get at their goals of helping students see the connections between different disciplines in science--as well as between science and their own lives--the Program is taught through the use of overarching concepts, ideas, and themes. No one textbook is used for the program.

The teaching in the Coordinated Science Program is different from traditional science teaching in that there are fewer lectures, worksheets, and drill activities, but more laboratory work. They follow the California Science Curriculum Framework standard of at least 40% of class time devoted to laboratory work.

Instead of listening to extensive lectures and doing worksheets, students in the Coordinated Science Program do a lot of labs and hands-on activities, including ones related to their lives. The homework assignments are longer than typical homework assignments and are not designed to have students simply answer questions at the end of a chapter. Students are asked to do writing activities with hopes that through writing, students would engage in the process of integrating knowledge and thinking with it.

In addition to conventional tests, students in many classes also engage in authentic assessments such as performances and portfolios. Performances and portfolios entered into the Coordinated Science Program because of the interest of a few teachers at the school.

It was through teacher collaboration that much of the important reform work occurred at Westview. This process created communication among teachers about developing materials and ideas for their classes. They depended upon each other's expertise for learning different aspects of subjects which they might not have known, as well as new instructional strategies. Teachers also got together to brainstorm their ideas, talk them through, and figure out how to put them into practice in their classes. In this context, mentoring of inexperienced teachers by the more experienced teachers was a routine and normal activity. The teachers who were not so creative benefited from the innovative ideas of other teachers. In addition to knowledge gained--and the more affective dimensions of this collaboration--teachers in the science department shared the work among themselves.

The teachers in the Coordinated Science Program were convinced that the coordinated approach is the most effective way of going about the study of science, in spite of the time and energy demanded to initiate and conduct it.

CASE STUDY OF EDISON HIGH SCHOOL

Stephanie Quate

Tucked away from the hubbub of a nearby Metropolitan city, Edison High School gives place to 1,200 students, 27% of whom are African American. Having been working at restructuring efforts for seven years, Edison has received assistance from such sources as the Coalition of Essential Schools and the Re:Learning program. The school has become a rich, supportive environment for teachers with innovative ideas who actively pursue ideas such as student as worker, personalization of instruction, and intellectual rigor. It has received further nudges toward reform from state legislation.

Since the state initiative is an attempt at overall systemic change, it has many components. At its heart is the assessment program. Through the assessment program, not only are students accountable for demonstrating mastery of content, but teachers are accountable for the quality of student learning. Based on a complex formula, each school is expected to raise the scores of students on each of three major assessments to reach a threshold score. Having students do well on the state assessments is a major goal for districts, schools, and teachers.

The curriculum reform at Edison High School has been guided by two complementary philosophies: that which is reflected in state legislation and the nine common principles of the coalition of Essential Schools. The change process is complex. Along with changing norms, schools must change structures, examine beliefs that underpin familiar practices, and develop new teaching strategies.

The goals of the curriculum at Edison stress higher order thinking and problem solving. These goals are for all students, not just the academically talented students. In a parallel manner, the content of the curriculum is focused on concepts, metacognitive strategies, and meaningfulness. It is not limited to facts nor is it limited by a belief that students become more knowledgeable simply by knowing more facts.

While overarching goals for reform were very apparent in the selected classrooms studied, the means to get to those goals were not always clear. In particular, a focus on *quality work* and *depth of thinking* was not always visible, even though the goal of students using their minds well drove the teachers' curriculum and instruction.

Assessment strategies often appeared to emphasize the completion of tasks rather than quality of thought. Rubrics tended to be checklists rather than descriptors of performance levels. Performances often were not judged by their quality but on whether or not they included the required activities. Students often were not asked to redo work of low quality. The teachers tended to grade on characteristics of presentations, such as attractive visuals and adequate volume, more than depth of thought of the research.

This is a school which strives for students to "use their minds well." Students are urged to think about serious issues. But in this well-nurtured school culture, an element is missing: the element of focusing on the goal of intellectual excellence rather than becoming confounded by the means to achieve the goal. The big picture of the reform movement is very much a part of the belief system of the school. The details of how to best implement the reforms are still under study, exploration, and experimentation. Pulling all the pieces together to make for a coherent whole is a long and arduous process. Edison may not be there yet, but it is moving in the right direction.

THINKING ACROSS DISCIPLINES AT OAKGROVE MIDDLE SCHOOL

Erin Rosen

The central philosophy at Oakgrove Middle School, a suburban school with over 1,300 students—predominantly students of color—is Outcome-based Education (OBE). Gleaned from literature published by the High Success Network, the three main goals of OBE are to: 1) equip students with knowledge, competencies, and orientations needed for future success; 2) implement programs and conditions that maximize learning success for all students; and 3) do the above with a clarity of focus by holding high expectations for all students, giving students "expanded opportunities" to learn well, and using curriculum developed by designing down from exit outcomes.

A committee of administrators, teachers, parents, business representatives, and students from Oakgrove identified five basic outcomes for students in the district: students are to be effective communicators, inspired learners, productive workers, responsible citizens, and resourceful thinkers. This list of exit outcomes is posted in all of the teachers' classrooms, but the teachers vary in their use of the outcomes. Although the teachers have received much in-house and external training in OBE, many of the teachers remain uncertain as to what OBE really is.

For the seventh and eighth grade Language Arts/History teachers at Oakgrove, the question of "what OBE looks like" has received particular attention in the past year. As recipients of a three year, $35,000 grant from the state, the Language Arts/History teachers have embarked on the task of rewriting their History curriculum. This revision process has given the History/Language Arts department the opportunity to coordinate its 7th and 8th grade curriculum, to write curriculum which has solid content, and to design this curriculum with the intent of implementing OBE philosophies and giving students the opportunity to meet the district's exit outcomes.

This strong content/OBE link provides a powerful example of how a subject area focus and OBE philosophies can be woven together. Over the course of the year, the Oakgrove History department designed units on such topics as slavery, civil war, and reconstruction which rely heavily on strategies such as group work, demonstrations of student knowledge, rubrics for self-assessment, and "expanded opportunities," a chance for students to redo an assignment in order to more fully meet the rubric requirements and/or the exit outcomes. The curriculum calls for students to be both the directors and assessors of their work, with the teacher playing the role of the facilitator.

Shifting to a situation where students are directors and assessors and teachers are facilitators involves a major redefinition of the teachers' and students' roles. Some classrooms at Oakgrove have yet to make this shift and others vary between traditional and reformed roles, but one classroom in particular is run with a clear understanding of new roles by both the students and

the teacher. In order to bring students to this understanding, the teacher of this classroom gave his students activities and assignments in the first month of school which were aimed exclusively at familiarizing students with OBE terms and philosophies such as exit outcomes, performances, rubrics, risk taking, expanded opportunities, essential learnings, and quality. These terms and philosophies were the tools the students used in approaching their academic work in the rest of the year.

The month of "training" in OBE seemed to give these students both a sense of understanding about their own learning process and a lens through which they could assess their individual schoolwork. Although only one teacher's students received this kind of focused training in OBE, the larger student population at Oakgrove engaged in significant self-assessments of their learning and schoolwork through the process of student-led conferences. During the student-led conferences, students discussed with their parents and teachers the progress of their work, their strengths and weaknesses in each class, and how they met the exit outcomes. The student-led conferences did much for all students' understanding of their learning and their work. The conferences also gave parents a personal look at OBE and what OBE means for their children.

There has been no community resistance to OBE at Oakgrove. In fact, there have been relatively few barriers to the implementation of the OBE philosophy at Oakgrove. This is not to say that the Oakgrove teachers and students have completely "arrived" at reform. Rather, Oakgrove has elements in place for the successful development of engaging, relevant curriculum and for the implementation of curriculum in a reformed manner, where students demonstrate their knowledge through life-role performances. It is this effective pairing of strong content with OBE strategies for teaching and learning that makes the Oakgrove example so powerful. Further training for both students and teachers in OBE and "what OBE looks like" in the classroom, trainings which perhaps could be led by Oakgrove teachers and students who are practiced in the philosophy, will greatly aid in the school's continuing progress toward reform.

CASE STUDY OF ROCKVIEW HIGH SCHOOL: THINKING ACROSS DISCIPLINES

Beverly Anderson Parsons

In August, 1988, Rockview High School opened its doors to over 1,450 tenth through twelfth graders, 18% of whom are minorities. Rockview High School was created in order to ease the crowding of students in the district's two other high schools. Taking advantage of the opportunity to establish a high school with a different orientation to teaching, the district superintendent facilitated the creation of a reform-oriented school. His initial step in this direction was to hire a principal from outside the district that he knew to be a forward thinking, innovative person. He gave her as much freedom as possible within the boundaries of a fairly traditional district.

In the winter of 1988, six months before the school opened, seven teachers were hired to work with the principal on initial planning. This group laid the groundwork for the organizational framework and curriculum of the school. Among other innovative decisions, the group decided to not have department chairs, to implement a flexible schedule, and to draw up a series of broad, reform-oriented belief statements for the school.

In 1991-92, the school published a statement of progress for the reform underway at Rockview, including aspects of its school-centered decision making and accountability processes, the changed roles with student as worker and teacher as facilitator, and its integrated core curriculum.

For the purposes of this case study, the research team focused on the work of one integrated core curriculum, the 10th grade American Studies Integrated Core, which combines US History, Language Arts, Science, and Fine Arts. Just as the selection of this core was being made, the teachers were deciding to focus on the "Perspectives Unit," an eight week unit placed chronologically during the Civil War and Reconstruction years. This unit became the basis of intensive study within this school-wide study.

For the Perspectives unit, the core teachers were interested in structuring a culminating activity that would meet their desires for reform in terms of integrated curriculum, employment of students' thinking skills, and student arrival at an understanding of multiple perspectives. In particular, the teachers were interested in addressing three problems they felt were present in students' earlier work: lack of use of supporting evidence, lack of student preparation, and lack of integration of subject areas in a sophisticated way.

In another unit, the increased clarity of the activity, the engagement of the students through playing the role of a Civil War character, the practice session, the specific rubric, and the greater coaching of students during the event all seemed to contribute to the increased success of the

activity as compared to previous endeavors. Although the teachers were generally pleased with this activity, the experience showed that these teachers and students of Rockview High School were still transitioning from traditional modes to more reformed modes. A look into six areas of reform-—goals, content, teacher role, student role, student work, and assessment—-will explain.

In terms of goals, the "essential learnings" for the Perspectives Unit were neither clear nor explicitly conveyed to students. The content has the beginnings of "reform" curriculum in that efforts toward interdisciplinary connections and "less is more" are being made. However, there was little interdisciplinary understanding on the part of the students and a lack of interdisciplinary instruction on the part of the teachers.

In order to understand the causes behind Rockview's current status of reform, the researchers compared the different modes and conditions of learning between teacher and student. They found that while the teachers had modes and conditions which met what research says is necessary for group learning, integration of curriculum, and responsibility for learning, the students did not. Although the teachers seemed to have a driving vision of a transformed classroom, they did not seem to have a clear idea of what they needed to do to achieve it, or, rather, to enable *students* to achieve it. Thus, students showed little ability to work well in groups, generally remained unclear about the connections between subject areas, and did not take on personal responsibility for their learning.

The Rockview community clearly has gone far down the path of reform and they are unlikely to turn back. The challenge now seems to be to achieve the major shift from emphasis on how to teach better to how to guide students in their learning. In particular, the emphasis needs to be on defining what students are to learn and how students best move to a strong emphasis on depth of learning and acquisition of thinking skills with strong content.

CROSS-SITE ANALYSIS OF THE CASE STUDIES OF CURRICULUM REFORM

Introduction

Although our individual case studies of curriculum reform convey important insights, the key messages that emerge from looking across the nine case studies *collectively* are even more powerful. Much of this power is due to the context in which these reforms have taken root--common everyday school settings influenced by various facets of the reform forces at work in the country.

The reform efforts that began in the U.S. in the early eighties have had many faces and continue to evolve. Many political forces at the national, and especially the state level, are influencing educational policy decisions with respect to curriculum requirements and means of assessment. The results of cognitive science research and studies of educational practice undergird many of the reform movements. Subject matter perspectives are reflected in the NCTM Mathematics Standards and the recommendations of various science groups. Common themes cut across these many reform influences, but nevertheless, reform has many faces and a somewhat different visage in each school setting.

The case study sites are a product of these multiple forces. They were not experimental sites designed by researchers to test their ideas, nor showcase sites developed by reformers as the ultimate expression of what they wanted or see put into practice. These sites were ordinary schools whose specific new forms resulted from the outworking of the many reform forces in our society. They were selected because there was evidence that their reforms were successful, even though they had to make change in the face of everyday constraints, limited resources, barriers to reform, and competing demands on educational practice.

These individual cases, and the cross-site analysis, highlight the inadequacies of a common misconception worthy of identification up front, namely the simplistic notion that the curriculum reforms under consideration here can be precisely defined and understood independent of the specific school context in which they are initiated. What occurs in practice is a reflection of these reform ideas in interaction with the specific context of each school setting. Reforms cannot be initiated in a uniform manner across schools independent of the culture of the particular school or department, or the history of educational practice at that site, or the professional competence and experience of its staff. The story that follows is a story of complexity and unevenness--in terms of events, context and the successes achieved. The major reason for telling the story is to identify key messages from these reform sites of interest to others who want to venture down some of the many pathways through the countryside of reform.

The Cross-Site Analysis Process

Each of the nine case studies was conducted by a different researcher but all were pursued under the same initial conceptual framework. The synthesis of the results of the cases, however, is not limited to matters explicitly identified in the prior conceptual framework. It attends to matters relevant to curriculum reform emerging from the cases themselves.

Analysis across sites began early in the case study process. Half-day meetings of the researchers were held approximately every three weeks during the research to identify common themes, compare results and plan subsequent data collection to test emerging understandings.

Conceptual framework. The framework used to synthesize the nine case studies below is drawn partially from a commissioned paper prepared for the Curriculum Reform Project entitled "Building Explanations Across Case Studies: A Framework for Synthesis" (Rossman, 1992). Of two alternatives provided there, a conceptual framework with the following three dimensions was employed.

Technical. Professional knowledge and skills, and the means by which they are acquired.

Political. Matters of authority, power and influence, including the negotiation and resolution of conflicts and moral issues of justice and fairness.

Cultural. Values, beliefs and school norms--both in terms of a general ethos and competing perspectives that contend with each other.

These three analysis dimensions have been "crossed" with three other major foci found within the cases: the nature of the reform sought, barriers to reform and essential ingredients of attaining reforms. Together they form the matrix pictured below which is used as the conceptual framework for the synthesis.

	Nature of Reform	Barriers to Reform	Essentials of Reform
TECHNICAL DIMENSION	*	*	*
POLITICAL DIMENSION	*	*	*
CULTURAL DIMENSION	*	*	*

Embedded within this conceptual framework are a number of important themes, concepts and perspectives, some of which could have been used as dimensions of an alternative framework for the synthesis. One theme used throughout the cases is the notion of *dilemma*, especially as experienced by teachers. This conception does not have a specific location in the analysis

framework, but rather is a matter of continuing consideration and discussion throughout. In particular, it is prominent in the discussion of barriers to reform.

Although not used as an explicit dimension in the conceptual framework, a dimension labelled "personal" was considered for inclusion. This personal dimension would have included, individual professional competencies, postures toward various political or policy initiatives, and personal values and beliefs, matters which are addressed respectively within the (1) technical, (2) political, and (3) cultural dimensions. Because it cuts across all three other dimensions, establishing "personal" as a separate dimension did not seem useful.

The personal considerations of people--especially teachers--involved in the reforms are prominent throughout the cases and interact with most aspects of them. As a result, discussion of these personal considerations will be found throughout all three dimensions of the cross-site analysis: technical, political and cultural. They will be noted most often with respect to the cultural dimension, however, because of their connection to values and beliefs. While considered most often in this cultural context, values and beliefs are clearly personal matters as well; individual values and beliefs may be in conflict with those of the school or department culture. Many of the dilemmas faced by teachers are related to various values and beliefs they hold.

An important orientation in developing the case studies has been the use of alternative perspectives, including especially: psychological, philosophical, socio-cultural, subject matter, and economic perspectives. They are important both as epistemological viewpoints and as realms of understanding that can inform a matter under consideration. Although not used as the conceptual framework, they have been kept in mind throughout the analysis and writing. These perspectives cut across all of the dimensions, but psychological perspectives are particularly relevant to the technical dimension, socio-cultural perspectives to the cultural dimension, subject matter perspectives to both the technical and cultural dimensions, economic perspectives to the political dimension and philosophical perspectives to all dimensions.

Analysis process. The actual cross-site analysis process itself included the following eight phases (after Rossman, 1992), the first two of which were completed in the process of defining and conducting the nine case studies.

Phase 1: Beginning. This phase entails locating the areas of interest that will provide the focus of the cross-site analysis.

Phase 2: Bounding the scope. "This phase places initial boundaries on the scope of the synthesis."

Phase 3: Inventorying the cases. This phase requires describing the following:

Focus. Describe the focus such as "the curriculum itself, implementation strategies, instructional practices, student outcomes, professional development, the culture of the classroom, professional associations or state agencies. The researcher should identify the primary focus of each case study and list it, perhaps in a matrix to facilitate comparison among the cases."

Goals. Identify and list each study's goals to help "the researcher understand the study's implications and potential parallels with others."

Scope. Identify the level of analytic interest, e.g., individual or nation, as well as the intensity of data collection and its duration.

Complexity. Identify the complexity, e.g., the number of classrooms involved and the mix of research methods.

Organization. Is the case organized "temporally, thematically, by individuals (students, teachers), or by some other means. These structures are part of the conceptual framework of the study and shape the conclusions presented."

Audience. Who is the audience for the report?

Phase 4: Reading the cases. "This phase entails immersion in the cases--repeated reading and reflecting on the texts."

Phase 5: Developing an interpretation of each case. "After immersion in the set of cases under consideration, the researcher focuses on each case in turn to identify the key metaphors that illustrate the central meaning(s) of the cases. This may be driven by a conceptual framework constructed prior to beginning the syntheses (always held tentatively, however) or may be more purely inductive ... lists of metaphors, concepts, and themes as expressed in phrases or vignettes are useful to construct. These represent the interpretations of the cases. The challenge here is to develop interpretations sufficiently general to be comparable to the other cases yet grounded in the details of the specific case."

Phase 6: Juxtaposing the cases. "Here analogic reasoning comes to the forefront as the researcher compares and contrasts the various interpretations. One case is like another in what ways? different? extends and elaborates? How do the central metaphors relate to one another both within the cases and across cases? Which metaphors provide the most explanatory power to capture the essences of the cases? Which metaphors most cogently, elegantly, and economically describe the set of cases? This process entails comparing themes, metaphors, and explanatory stories across cases. During this phase, it is likely that comparing the interpretations will lead to new insights into the cases--a reconceptualization of the entire work. Here, as in Phase 2, the use of matrices can enliven the process."

Phase 7: Synthesizing the cases. "'We are no longer dealing just with observables [cases] but also with unobservables [interpretations], and are connecting the two with successive layers of inferential glue.' This 'inferential glue' is the stuff of synthesis, a grounded theory of the subject that tells us something new while preserving the sometimes contradictory specifics of the cases."

Phase 8: Writing the synthesis. "This final phase entails writing the synthesis which should be true to the original purpose of the work, crisp in style, loyal to the details of the cases, but provide a more complex understanding of the subject than does any single case." (Rossman, 1992)

Systemic perspective. While a cross-site analysis of cases based on a 9 cell matrix has the potential of appearing as a set of discrete components, a major theme of this analysis is the interconnectedness of the many components. It is important to consider the interactions found across the cells. Maintaining a systemic perspective is essential. Subsequent attention to models based on the work of Senge is a logical culmination of the analysis.

The following presentation of the analysis is organized into three major sections based on the three case foci identified above: the nature of the reform sought, barriers to reform and essential ingredients of successful reforms. Within each of these sections attention will be given to the three analysis dimensions: technical, political, and cultural.

Nature of the Reforms

A major theme of the literature review conducted prior to the case studies was that *the desired reforms are complex, multi-faceted and extend into the most basic aspects of the teaching and learning process*. This same theme emerges from the case studies themselves. What was found in the schools studied were change endeavors that were multi-dimensional, highly interactive and connected with the most fundamental aspects of teaching and learning. Furthermore, as will be discussed in considerable detail in the following section on barriers to reform, their depth is such that *achieving the desired reforms demands great effort and commitment expended over a substantial period of time*. The educational reforms described in the NCTM Standards, the publications of such science reform groups as AAAS's Project 2061, NSTA's Scope, Sequence and Coordination Project, and more recently the National Research Council, and the more general educational reform groups such as the Coalition of Essential Schools and the High Success Network are truly of major proportions.

Although our nine cases were quite diverse--in spite of being selected because they were successfully initiating reforms--they had much in common with respect to the reforms they were seeking. The earlier literature review documents the theoretical basis for much of the reform; our case studies address what these reforms look like in practice. Given the difficulty of initiating these reforms, it is not surprising that we found great variation from one teacher to another in the extent to which these practices had been initiated. Nevertheless, within our cases we found

displays of the reforms which make concrete what has been advocated in various reform documents. To further describe these reforms, they will be addressed within the three dimensions of technical, political, and cultural.

The technical dimension. This dimension focuses upon the teacher knowledge and skills needed to bring about the reform and the means by which teachers acquire them in the reform context. It must be noted as well, however, that it includes new knowledge and skills for students in classrooms (e.g., with respect to self-directed learning) and for policy-makers and top administrators (e.g., with respect to sharing power and authority and fostering new visions of education.) The new knowledge and skills for teachers are in *curriculum content* and *pedagogical approach*.

Curriculum content. The new content orientation is fairly straight-forward and obvious both from reading the new standards in national reform documents--or state curriculum guides based on them--and examining curriculum materials intended to reflect these standards. The focus is on major concepts and themes rather than discrete items of isolated information and the accumulation of facts. The new orientation gives significant attention to the connections between these concepts and the means by which scholars acquire this knowledge and between these concepts and their personal and societal applications. The focus now is upon integrated content rather than isolated disciplines or subject areas.

The pursuit of this new orientation is evident in our cases--although not always fully attained--as illustrated in the following statements.

> In general, the content in a reformed classroom emphasizes conceptual understanding.

> The goals included (1) mathematics content that is more advanced and organized somewhat differently from conventional texts (i.e., organized around problem topics rather than conventional topics), (2) student work involving more explorations ... The program integrates mathematics "strands," links content to real-world applications ... and emphasis on written and oral communication.

> The content of this program looks very different from traditional secondary science education. Absent are the lists of vocabulary words and the emphasis on facts such as learning the parts of the flower, or "dissecting frogs and learning all the parts," or naming all the bones of the body that are isolated from the rest of the curriculum. What has traditionally been perceived as science content is now embedded in a conceptual approach to learning "how science works."

> The goals ... focused more on higher thinking than on learning discrete information.

Pedagogical approaches. In contrast to curriculum content, the new pedagogical approaches are more diverse, their demarcation from traditional practice less apparent, and their acquisition by practitioners more complicated. While based on fairly well understood constructivist perspectives on learning, their reflection in *teaching* is not as clear-cut. This pedagogical approach potentially has many different components, but the presence of a few--or even many--of these components

does not necessarily mean the pedagogical reforms are in place. The manner in which they are used greatly influences whether or not students are acquiring depth of understanding, engaging in authentic problem solving, or applying their understanding in new contexts.

In cross-site discussions by the researchers, the following emerged as a portrayal of the new orientation being sought in the various reform sites.

43

Traditional--Reform Pedagogy Continuum

Predominance of Old Orientation	Predominance of New Orientation
Teacher Role:	
As dispenser of knowledge	As coach and facilitator
• Transmits information	• Helps students process information
• Communicates with individuals	• Communicates with groups
• Directs student actions	• Coaches student actions
• Explains conceptual relationships	• Facilitates student thinking
• Teacher's knowledge is static	• Models the learning process
• Directed use of textbook, etc.	• Flexible use of materials
Student Role:	
As passive receiver	As self-directed learner
• Records teacher's information	• Processes information
• Memorizes information	• Interprets, explains, hypothesizes
• Follows teacher directions	• Designs own activities
• Defers to teacher as authority	• Shares authority for answers
Student Work:	
Teacher-prescribed activities	Student-directed learning
• Completes worksheets	• Directs own learning
• All students complete same tasks	• Tasks vary among students
• Teacher directs tasks	• Design and direct own tasks
• Absence of items on right	• Emphasizes reasoning, reading and writing for meaning, solving problems, building from existing cognitive structures, and explaining complex problems

This pursuit of this new orientation to teaching was found across the cases, whether they were science, mathematics or general cases. Illustrative of this fact are the following.

The teacher role in a reformed classroom is that of a facilitator of learning. In this role, the teacher helps students process information, models the learning process, and facilitates student thinking.

In general students feel as though there is more dialogue both between the teacher and the student and between students. The group work means that the classroom is decentralized, the teacher spends less time lecturing, and the students spend more time interacting, and they have more one-on-one interactions with their teacher ... Extrapolating from the statements about the curriculum, students are expected to participate in problem formulation and problem solving activities, to communicate about mathematics, to reason mathematically and to make connections between mathematical concepts and across contexts.

One of the ways we get students to function as workers is through higher order thinking skills. Students predict, compare, contrast, or tell why a turning point is significant. Our role is different, too. We facilitate, not disseminate. Our goal is to nurture classrooms where people think.

At the heart of this new approach to teaching is a dramatically different role for students. This new role of students is illustrated further by the following.

The students in the interactive classes were asked to take a much more active role in their learning. They were being asked to wrestle with problems--situations in which no path to solution was readily apparent--on a daily basis. They were asked to figure out how to solve these problems and why these solutions worked. They were asked to rely on other students for help, and to offer that help to others when they needed it. They were to turn to each other rather than the teacher. They were asked to take over the role of presenter from the teacher, even when they were not clear themselves. They were asked to deal with their inevitable frustration when trying to do something they did not already know how to do. Finally, they were asked to participate actively in the assessment of their mathematical progress.

During the assessment it was clear that students were indeed taking charge of their learning. They selected the question on which to focus; they designed their presentations within the structures handed them; and they initiated the presentations themselves.

Students observed by this researcher were often engaged in the following behaviors: developing hypotheses, collecting data, writing about their learning, exploring through hands-on activities, and working in cooperative groups. They were engaged in these activities more frequently than the more traditional activities of listening to lectures, reading a textbook, or answering written questions on worksheets.

... the students must learn how to use the graphing calculators, the computers, and the software. Additionally, students must learn how to work in a cooperative group, how to make class presentations, and how to do the research required to answer the questions posed in the units. Even the homework is different. Project homework requires students to write more, to read more, to be able to explain an answer, and to be able to work with problems that are presented in the context of some "real world" applications.

Although teachers often did not fully attain this orientation and students often resisted this change in expectations, it was this new pedagogical orientation that was being sought by the reformers in these cases.

The political dimension. This dimension addresses matters of authority, power, and influence. It extends to matters of negotiation and resolution of conflicts as well, and includes such situations as relationships among teachers within a particular department of a school, parent-school relationships, and teacher-administrator relationships. Moral issues, such as matters of fairness and justice, enter into the political dimension as well.

Decentralization. The nature of the reforms being sought generally are associated with decentralization of power and delegation of authority to lower levels within a given hierarchy. Individual schools are given more authority to make curricular and instructional decisions on their own, independent of district policies that impose uniformity on all schools. Teachers within a department of a school are given increased freedom and responsibility for making curricular

decisions. This downward shift in power extends to students as well; teachers give students the freedom--and encouragement--to engage in self-directed learning.

Operationally, the situation is complex; it must be understood systemicly. Parents, for example, have a vital interest in their children's education and often choose to exercise their influence through a variety of informal means, as well as formal means such as appearing before the school board. What may appear initially to be simply a teacher-student matter, is a matter of vital interest to a much wider group. The goal is to de-centralize power in a manner that empowers all stakeholders.

Another important component of the picture is the availability of resources. Without the resources for implementing a decision on changing the curriculum, for example, the power of a school department to decide to change the curriculum may be a very limited power. Real decision-making power includes a certain degree of control over resources. Reform does not necessarily mean an increase in resources, but it does imply control over their expenditure by those responsible for educational results.

Collaboration. Empowerment is not just something given from above by people in authority who decide to decentralize decision-making. Teachers in a department may gain power through the act of collaboration itself. This collaboration may result in increased strength of convictions on a curricular matter, greater clarity as to the nature of a curricular change, and greater knowledge and skills. The power of collaboration in these cases often was of major proportions.

This collaboration may take place in informal settings or in the context of formally established processes, as illustrated by the following situation in one of the school-wide reform endeavors.

> A major decision made early in the planning of the school was to not have department chairs. Instead, the department chair duties were split up among members of a department. Without department chairs, decisions about courses are made through the curriculum committee which has about 20 people, with each department represented. The committee looks at proposals for courses and evaluates whether or not the proposal meets the vision of the school. The principal is present at the committee meetings and gives input but has no final decision-making power.

Another example is embedded within the culture of an individual department. Its informal nature is highlighted by its presence within a department where the formal mechanisms are experiencing some difficulties.

> ... the impetus to change and improve comes from individual mathematics teachers rather than from state, district, or administrative mandates ... The process of change is ongoing at Fruitvale High School. As the force and intent come from within the staff of the mathematics department, the culture, politics, and power of that department are the important aspects of the reform process.

An example from another department illustrates that this collaboration can be the very foundation of a reform endeavor.

The context in which this communication and collaboration has occurred is in the development and planning of the course materials and instructional activities. Meetings are not held simply for the purpose of communicating information; they are held to accomplish specific work that needs to be done. At the same time, the teachers themselves recognize that the key to getting this work done is communication ... One of the collaboration outcomes is that the teachers in the science department depend upon each other's expertise. As a result, a great deal of learning from each other occurs among the teachers.

A major goal of the reforms is student self-directed learning, which is, in effect, an extension of this decentralization of decision-making and collaboration to the next level.

Moral considerations. A goal of the reforms is justice and fairness for *all* students--most often expressed as a commitment to educational excellence for *all* students. There is an expressed commitment to equality of educational opportunity and achievement regardless of gender, ethnicity, or career path. It is a commitment to educational excellence for all students whether they are bound for college or the workplace upon completion of secondary schooling.

In school practice these values may be expressed in varied ways. A common expression of these values in the reforms under study in these cases is a commitment to the elimination of tracking of students. Since not all teachers are convinced that the elimination of tracking is the best practical expression of equity and excellence, this example provides yet another hint of the previously mentioned conflict and struggle inherent in a significant reform endeavor. A moral issue is at the heart of a political matter having to do with power, authority and resolution of conflicts.

The cultural dimension. Values, beliefs, and school norms--both in terms of a general ethos and competing perspectives that war with each other--have a powerful influence upon what reforms are sought in a given case, as well as a powerful influence on how readily the reform can be made and what form it actually takes in school practice.

A number of values are embedded prominently in the desired reforms. For example, there is a strong commitment to quality science and mathematics education for *all* students, not just those who are college-bound or who are headed for a science-related career. In many contexts, this is translated as valuing heterogenous grouping of students and the elimination of tracking. Another embedded value is the greater worth of learning fundamental content concepts and interdisciplinary themes over discrete pieces of information. The connections of content to other content and to their applications are valued as well.

A number of beliefs about teaching and learning are prominently embedded in the desired reforms as well. These beliefs--most well grounded in extensive research--include what are often labelled constructivist principles of learning, such as learning being contextual, based on prior conceptions, socially negotiated and dependent upon individual's personal construction of their own understanding.

... the Project believes ultimately the teacher's job is to teach students to be self-directed learners.

These beliefs about learning extend into a variety of beliefs about teaching as well. While these beliefs about teaching also generally are grounded in research, explicit understanding of what this teaching looks like in practice is not as complete as in the case of the beliefs about learning. The vision of student learning is clearer than the vision of the teaching required to produce this learning.

These values and beliefs may be in conflict with the traditional ones generally held in the school culture, by a particular department, and/or by an individual teacher. What is being sought is a change in the culture of the school--a change in educational values and beliefs about how learning best occurs. In effect, what is being sought is conflict, tension and the related hard work needed to resolve the conflict and tension as part of a process of improving education.

This description of a climate of change hints at some of the barriers to be addressed later and at the means of clarification, consensus and/or accommodation that may be essential ingredients within a school or department that successfully engages in reform. This interrelationship between the nature of the reforms, the barriers encountered in their implementation, and the essential ingredients of successful reform cases highlights once again the fact that the desired reforms are complex, multi-faceted, and extend into the most basic aspects of the teaching and learning process. Furthermore, it also provides an indication of the prominence of a second theme that will become prominent in this cross-site analysis: achieving the desired reforms demands great effort and commitment expended over a substantial period of time.

Barriers to Reforms

Change is not easy. This common shibboleth has ample support in our nine cases. The need for great effort and commitment over a long period of time to achieve desired changes is produced by dilemmas experienced by teachers. These dilemmas are numerous and have their roots in many places; they are, in fact, rooted in all three horizontal dimensions of the matrix which provides the conceptual framework for this cross-site analysis: technical, political, and cultural.

The technical dimension. Having the needed teaching knowledge and skills to bring about the reform is an issue in all of the cases, although not explicitly identified as such in all the case reports. In every case, some steps were taken to help teachers acquire the needed competencies, but the means of doing so was varied.

Limited ability to teach constructively. Even in the case of individual teachers who had a commitment to teaching for understanding and the development of critical thinking, there generally was a lack of full understanding of *how to do it*. For such teachers their dilemma was valuing teaching for understanding but not knowing how to organize and conduct their instruction in a manner that would produce the desired results. The specifics of the tensions

experienced by the teachers varied, but the root problem was that they did not know how to achieve the results they desired. Furthermore, the steps taken to assist them in this regard fell short.

One case illustrates a phenomenon found in all of the cases--teachers did not find it easy to change their role.

> Probably the hardest role for teachers to abandon as part of the reform was that of teacher as transmitter of knowledge ... Teachers may have valued student questioning, exploration, thinking, and explanation, but may still have engaged in large amounts of teacher talk, explanation, and lecture ... It appears, though, that some teachers took on the roles of the cooperative team members--communicator, manager, tracker, and team member--in their classrooms, and that they seemed to get in the way of students taking on that responsibility. The less students assumed these roles, the less they become responsible for their own learning and the responsibility for student learning then seemed to reside with the teacher.

This inability of teachers to shift their role obviously was a barrier to students taking on the role expected of them.

> There were times, though, when teachers did not permit or provide space for students to pursue the answers to their questions. Teachers may have perceived student questioning, decision-making, and/or actions as making a mistake and they may have stopped students in this type of questioning process.

Prior commitments. In other instances, the desired end product was not only unclear, but there was a commitment to a specific traditional instructional practice that stood in the way of moving on to new forms of instruction. Such a common barrier was a commitment to the textbook as a primary mode of instruction. Sometimes this commitment was rooted in a belief that it was important for students to learn in this manner.

In other cases this commitment to the central role of the textbook was rooted less in a belief in its efficacy and more in a pragmatic persuasion that it was the optimum way to teach given the time they had available or other constraints. This commitment is illustrated in one of the science cases.

> One teacher thought the most difficult aspect of the reform was the lack of a textbook. This teacher said, "Well, you know, when you have a class of 30 students come in, and you can say, 'Open your book to page 24' and give an assignment, or we read and have you discuss, you have a focus point ... And that was the hardest thing, is to keep the momentum going one class after the next after the next."

> None of the students interviewed said that they missed using a text or wanted to go back to a textbook. Some of the teachers, especially those new to teaching, said that they would like having a textbook as a companion to the project. Their main reasons were that they would have something that the students could take home and that they would also like to have something to fall back on if the class became disruptive.

Indications are that textbooks are a more important part of the learning process from the perspective of teachers than from the perspective of students. Such prior values and beliefs about

educational practices are a barrier to the reforms if these values and beliefs would have to change for the reforms to flourish.

The challenges of assessment. Another arena in which teachers faced a steep learning curve was in performance or authentic assessment. The specific skills of assessing in this manner take time to acquire and in many instances are not high enough in priority to earn an adequate place in the competition for space in inservice education programs or on the agenda for collaborative effort in departmental planning.

The challenges of doing classroom authentic assessment took many forms. When done well it enhanced student learning.

> Where the students have a strong sense of their "reformed" role, have a solid sense of "quality work," and are skilled in critiquing their own work, their demonstrations and performances exhibit the premises and principles of OBE; success is breeding success and high expectations are being met by all students.

When not done well, the new forms of assessment were a detriment to good education.

> The questions they asked were intended to probe the students' insights, although any student response seemed to be acceptable. Even though one of the goals of the assessments, according to Nancy, was to make the students critical thinkers, none of the students were required to offer proof for positions, make predictions based on evidence from the past, or integrate contemporary knowledge with historical events ... Student reasoning was accepted as if an opinion of any sort were better than no opinion ... Generally, grades were based on the surface qualities of the presentation, such as attractive visuals and adequate volume, rather than the depth of thought of the research. What was missing were standards describing the expected levels of performance. What was emphasized, instead of content and depth of knowledge, was the quality of the presentations.

Often the difficulties were embedded in a lack of clarity of purpose for the assessments.

> Since the expectations for quality of work were not clear, students interpreted the assessment tasks as reshaping learning from earlier lessons rather than creating tasks which emphasized reasoning and clarifying complex problems.

> Thus the Core teams seems to have gotten as far as focusing on certain themes and overall questions for students to address, but they have not clearly articulated the learning goals for students ... The assessment aspect of the Core team studied was a tangled web of confusion of purpose and perspective.

> An effort to rethink assessment would have to begin at the core: What is the role of assessment? Is its purpose to impose a grade or is its purpose to engage students in their own learning process as a form of self-evaluation? As teachers struggled with these questions, they brought up the factor of time ...

As with other dilemmas teachers faced, this matter of time as a constraint on improved assessment is a central factor across all of the cases.

> The time constraints were such that they were able to do only superficial evaluation of the success of the activities each time.

Interwoven with this constraint of time is a lack of understanding of *how* to conduct this new form of assessment and the initiative for acquiring this understanding.

It may also have been that they did not have clarity about how to evaluate the success of a given activity. For example, they expressed to one another their disappointment with the debate, but they did not engage in a thorough analysis of why the debate was not very successful.

In addition, teachers are constrained by the continuing presence of the traditional grading system with the accompanying expectation on the part of both students and parents that grades be "objective" and easily explained.

One problem is that teachers still must wrestle with the traditional grading system of the district. Teachers are required to give a percentage grade on the report card.

The new grading schemes were described by many students, parents, etc. as "subjective."

They had a need to justify student grades objectively and often felt at a loss when parents confronted them about grades which were assigned subjectively.

Assessment of student learning is a matter of concern for teachers in two quite different ways. One focus--addressed above--pertains to assessment conducted by individual teachers for purposes of diagnosing student learning and assigning grades. Such new assessment approaches as performance or authentic assessment generally demand that teachers acquire new competencies in order to shape their instruction to the reformed agenda.

The second assessment focus is large-scale standardized testing in which student performance can be compared across classrooms, schools, districts, states and even countries. This second assessment focus does not demand significant new competencies from teachers. It does relate, however, to teachers' values and beliefs with regard to testing, a matter to be addressed within the cultural dimension below.

Difficulties of group work. Various new forms of student group work also are part of reformed education. For many teachers, particularly in science and mathematics, these approaches are new and require skills they do not yet have. It is an additional barrier, although one that teachers seem to overcome more readily than the assessment barrier.

Most teachers acknowledge that experience and knowledge of effective cooperative learning strategies are critical to successful implementation of the science curriculum and that training in cooperative learning has been especially important.

It became apparent in observing classes that for many teachers this cooperative approach to learning had become second nature and was reflected in general interactions in the class, whether or not students intentionally had been put into groups.

The challenge of new teacher roles. This use of student group work is but one illustration of the changed role for teachers. Taking on a role that is less presenter of knowledge and more facilitator of learning is not a simple matter. It is a major role change that demands more than the simple technical acquisition of some new knowledge and skills. The acquisition of new teaching roles is a cultural matter as well, in that it is closely related to teachers' beliefs about effective learning. Thus, we will return to the topic again within the cultural dimension.

Acquiring the needed new teaching skills is a formidable and long-term process. Teachers often know what they do *not* want their classes to be, without being able to translate this conviction into a form of class instruction they do want.

> [In the] process of removing himself from the classroom as lecturer, he has not set up an alternative structure. Instead, in the students' minds, he has disappeared.

> The challenge, however, seems to be whether they can break through to a truly reformed teaching and learning strategy or whether they will wander about in the desert of many partially developed techniques that do not produce high level thinking and learning among students.

The challenge of new student roles. This new conception of the teaching role is rooted in a new conception of the students' role and the nature of the work they do. Putting this new student role into effect demands new skills and knowledge on the part of the teacher. The new student role depends less on recording information from the teacher, following detailed teacher directions, and memorizing information. It has more of a focus on interpreting and explaining information, and designing one's own activities. Student work is characterized less by completing worksheets and engaging in exactly the same actions as other students under the teacher's explicit directions. It has more of a focus on tasks that vary among students and are designed and directed by the students, either individually or in groups. It is student directed work that emphasizes reasoning, solving problems, and reading and writing for meaning.

A barrier to reform is that students often are not prepared to take on these new roles. To the extent that the new orientation does not run counter to student beliefs about what constitutes good education (e.g., what is needed to prepare for admission to a top-rank college), students generally are ready to assume new roles, if given the help needed to do so. Providing this help is a central requirement of the new teacher role, but one with which many teachers seem to have difficulty. The challenges are great as illustrated in these cases.

> Students were not specifically taught how to engage in creative planning, thoughtful evaluation, risk taking, and research strategies that they would need to build and demonstrate during the year. Students tended to focus primarily on completing an assignment rather than developing their ideas or learning particular skills. Students' experiences with evaluation strategies tended to be primarily that of having teachers judge their performance for the purpose of grading. They were not involved in much peer review of practices of performances.

> In general, kids were unclear regarding the intentions of the staff in the math department, and the notion that they should be constructing their own knowledge was something that they resisted.

One teacher spoke about how the hardest change that she encountered with the reform curriculum was teaching students the cooperative learning.

While some teachers found it hard to productively engage students in cooperative learning, there were other departments where such forms of learning had become second nature.

It also is clear from my observations of classes that students had learned to work in groups effectively and did it with comfort and ease. Teachers made reference to the fact that students had learned how to work in groups, even though they may not have been particularly skilled at it prior to coming into a Coordinated Science class. These skills which enabled them to work effectively in groups were varied and even included simple social skills.

After they had been in the program for a year, by the time they go to the second year, they are so malleable it is absolutely unbelievable. Groups--I mean they are willing to get into a group; they are willing to do fifty different activities per hour ... They don't question a lot of things that I think that they would have otherwise.

Changing this student role to smoothly incorporate cooperative group learning clearly is possible, but it takes an extended period of time--as indicated above--to bring it about. The challenge of helping students acquire new roles, however, is a much broader challenge than simply teaching students how to work in groups. Changing such student roles requires very explicit help from teachers.

It also appeared that students needed a lot more guidance on *how* they might become self-motivated learners ... Teachers will need to help students learn and apply the thinking skills in order to move forward to the point where students are focused on a conceptual understanding of the content rather than simply learning facts ... The challenge in continuing to change the teacher role is in how to facilitate the higher level thinking skills. Changing the teacher role goes hand in hand with changing the student role.

Acquiring the necessary broad set of teaching skills is a challenge for many teachers. In none of our cases had the group of teachers acquired all of the skills and knowledge required to fully implement the new form of education in their classrooms. This finding is not surprising when one recognizes the extended time required for teachers to acquire a new teaching strategy and the comparatively limited time devoted to this learning in our cases. Acquiring the needed competencies is a long-term process and the teachers are still "in process."

Inadequate inservice education. The need for new teaching competencies highlights the need for appropriate inservice education offered over a sufficiently extended period of time. In some instances, considerable dependence was placed on formal inservice education. In other instances, the means of acquiring these competencies was more through on-the-job teacher collaboration. In no case was there an indication that a group of teachers had acquired the full set of competencies needed to fully implement the reform.

In several instances an apparently good program of inservice education was terminated or scaled down before participating teachers had reached an adequate level of competence. There was a seeming lack of awareness of the depth of assistance required, the need to relate this assistance to

the day-to-day work of the classroom over an extended period of time, or the interaction between acquiring such competencies (the technical dimension) and changes in values and beliefs (the cultural dimension).

Since the technical dimension under discussion here interacts with the political dimension and especially the cultural dimension, it may not always be clear whether a teacher's difficulties with the reform are due to a lack of technical knowledge and skills or due to values and beliefs that are not consistent with the reforms. The technical component of the dilemmas teachers experience clearly is important but it cannot be considered without regard to the other components. Thus, this matter will be revisited in the latter sections on political and cultural dimensions of barriers to reform. They must be addressed systemicly.

The political dimension. The various barriers to educational reform have prominent political components reflected in unresolved conflicts and inadequate allocations of resources. These barriers include the following.

Limited inservice education. The long-term nature of the technical assistance required for reform poses a political problem in that most of the external means of providing this help were established for shorter time periods than required to do the job. Apparently, this inservice education and related assistance were based on the assumption that the goal could be attained more quickly than in reality is possible. In many of the cases, inservice education which was helpful in implementing the reforms ended before teachers had received all the help needed. In both middle school science cases, for example, valued inservice education was provided over a period of a couple of years, yet was terminated before many of the teachers were ready to carry on on their own. Similar situations exist in most of the other cases.

Teachers need ongoing, long-term support that goes beyond what is typically provided. The needed support is not just in the technical arena, but extends into the cultural arena as well. Political steps are needed to insure the availability of the required technical assistance and its incorporation with the process of addressing related values and beliefs. Important steps must be taken to insure that important cultural aspects--i.e., relevant values and beliefs--are addressed adequately in this inservice education.

Parental resistance. In a number of cases there is strong resistance to the reforms from parents. While this resistance has its roots in parents' values and beliefs--the cultural dimension--it clearly is a political issue as well. In many cases the intensity of parents' opposition was sufficient to significantly hinder the reform process. In one math site, for example, the administration's approach to negative parents was one of compromise resulting in the *de facto* tracking of students. It also can constrain the work of teachers as seen at another site.

Finally, perceptions of community expectations being counter to reform efforts serve to paralyze the teachers' forward-looking efforts.

Such situations raise questions about the appropriate response to such pressures, including the possibility of modifying the reforms in response to real and/or perceived problems with them, and the possibility of educating parents so they can address these issues from a position that is as fully informed as possible.

For whatever reason, this resistance was strongest from parents whose children were most able and successful by traditional indicators of success in school.

> Probably the students that had the most difficulty with this role were the students that are perceived as talented ... [T]he students who are really capable or have been really capable in the past in science where they had worksheets and learned vocabulary words find themselves not nearly as successful now because they are having to think and interpret and reason where they didn't have to do that before ... [T]hey go through a period there where they think, "This is the pits! You're making me do things that I don't know how to do."

Unresolved teacher conflicts. In most of our cases, teachers had a fairly high degree of autonomy and the freedom to make important decisions about how they would conduct education--both individually and as a department or team. In this context, however, one also found conflict as teachers engaged in their personal struggles to make change and deliberated with their colleagues as to what changes should be made. Given the reform context, such conflicts are to be expected--probably even desired--since such conflict is an inevitable part of change. The issue is not the presence of conflict, but what steps are taken to resolve it. In a few instances the means of resolving conflicts were inadequate and the result was tensions that inhibited progress on the reforms. Some examples of "counter-reform" convictions of teachers in the math sites are informative.

> Memorization and manipulation of facts and formulas was good for some kids, and the practice of memorization through the study of formulas would prevent kids from getting lazy, according to these teachers.

> ... most of the teachers are concerned that their students are not learning the basic skills, that they not getting enough "math".

> This pull between the "back to the basics" emphasis on factual knowledge and the emphasis on conceptual knowledge is an unresolved struggle in the mathematics department at this site.

> By the spring of the 1992-93 year, the mathematics department at the school had fractured into three camps of roughly equal size. The "interactive" teachers, including the department coordinator and the two teacher-leaders, were committed to the INT program and more generally to the changes it embodied. The "traditional" teacher disagreed with aspects of the INT program and its effects on the department's offerings; their dissatisfaction had been building and they had become more openly critical. A third group of teachers had taken positions between these extremes. They liked certain aspects of the new approach, were unsure about others, and were taking a wait-and-see position.

While conflict about such matters generally had been more fully resolved in the science sites, it was an issue there as well, as illustrated by one middle school science site.

The amount of science content especially concerned Linda. She said that there were some things that the students had to know, like the symbols for the elements, and the only way to know these things was to memorize them ... Two of the teachers felt that the philosophy which provided the basis of the reform program conflicted with their own personal philosophy of teaching, their teaching style, and/or the practicality of the situation--such as the availability of materials.

This apparent conflict over educational issues, however, is highly interactive with the availability of teacher support for making change. In the case of this science site, there were many indicators of inadequate help--through inservice education or collaborative working relationships with other teachers--for teachers in their individual struggles with these issues.

The 8th grade teachers were concerned with what they perceived to be a lack of organization and preplanning during their first year of implementation. Other teachers attributed their discomfort to the teachers' unfamiliarity and struggle with something new. The teachers who had been with the project for two or three years stated that they saw a big improvement in this area after they had been through it.

In some of our cases such conflicts largely have been resolved, but nevertheless, they are somewhat of an issue in all of the cases. The steps required to address such situations are fairly well understood, judging by the research literature on the issue. Putting such knowledge into practice, of course, often is difficult. The message from our cases is that such issues are important and steps should be taken to address them. In that sense they are a political matter; resources must be allocated and steps taken for the purpose of conflict resolution and assistance in addressing the related technical issues.

Lack of resources. In our cases the lack of equipment and other facilities was rarely a significant *direct* barrier. Somehow, the resources were found to acquire the essentials. In an *indirect* manner, however, resources often were a significant problem when their lack resulted in members of a department not being physically located in classrooms next to each other. As will be discussed in more detail later, collaboration among teachers was a highly important factor in these reform endeavors. In cases where teachers were not located near each other, an isolation resulted that often was a significant barrier to collaboration. One example was a middle school science site.

Regarding the 6th grade pilot teacher (Sara) and two 7th grade teachers: "These three teachers, Sara, Paul and Connie, felt they had 'ownership' of the program and felt comfortable with making changes because 'the curriculum was written by teachers just like me..in fact, I was one of the teachers.' They also had classrooms that were in close proximity to each other which facilitates collaboration ... Due to the middle school structure they also had a more difficult time finding time to work with other science teachers, especially when their rooms were physically removed from other science teachers ... During my discussions with Sara [the lead teacher] she was not aware of what the other science teachers were doing in her building and teachers new to the reform had the feeling that 'they were going it alone.'"

Justice and fairness. There is a barrier to reform that grows out of the goal of justice and fairness for all, a goal generally expressed as the elimination of tracking and ability grouping, or

in a specific subject area, as "science for all students," for example, rather than just for the college-bound students.

Because of the differences in judgment about what constitutes fairness, however, it may be difficult to say *how* this goal, or its absence, is a barrier to reform. It is highly interrelated with the cultural dimension. In communities where the elimination of ability grouping or the absence of special classes for gifted students have become contentious issues, this matter is very much a political issue. It relates to how decisions are made within a school and how conflict in a community is resolved. It also may be related to the cultural dimension, in that it is highly intertwined with teachers--and parents--beliefs about the value of various learnings--what and for whom--and beliefs about what learning outcomes are most important for various future goals--such as college--and what constitutes the most effective way to learn.

By and large, the goals of the reformers have been ones of fairness and justice. The barrier arises when conflict occurs at a given site--between professionals and/or between professionals and parents--over what constitutes fairness for various categories of students. To a large extent, this specific barrier will be removed when the desired progress is made on fostering positive political processes and addressing value and belief issues within the cultural arena. In doing so, it must be emphasized again that shifting from traditional to reformed educational practices creates numerous dilemmas for teachers and achieving the desired reforms demands great effort and commitment expended over a substantial period of time.

The cultural dimension. From many perspectives, this section on the cultural dimension of the barriers to reform constitutes the focal point of the cross-site analysis of the cases. It is central because it deals with fundamental values and beliefs about education held by the people involved--values and beliefs that are at the heart of their commitment to a traditional or reformed outlook on educational practice. If there is a consensual set of values and beliefs among the teachers that is consistent with the reforms, this barrier is essentially eliminated. In fact, it is now a powerful force for change in the reform direction. On the other hand, if there is no consensus, reform has a long ways to go.

If in the process of putting the reforms into practice, consistent shifts in values and beliefs occur, the reforms probably will be in place for the long term. If the parallel shifts in values and beliefs do not occur, the reforms probably will disappear as soon as the special efforts of the reform endeavor are removed from the picture.

Although presented here under the label of "culture," these values and beliefs have a strong individual as well as social component. In many cases, there is great variation among a group of teachers on these fundamental values and beliefs. In such instances, major collective changes face serious difficulty. In other instances a consensus consistent with the reform agenda exists--or as a result of working together, one emerges--and reform occurs quite rapidly.

The use of the technical and cultural dimensions in this analysis highlights a distinction between two types of barriers that may not always be easy to distinguish. As noted earlier, people providing inservice education generally focus on the technical dimension and may not attend fully to the cultural dimension, i.e., related values and beliefs of the teachers. As noted earlier also, it may be hard to determine whether or not a teacher's difficulties with a reform are due to a lack of technical knowledge and skills, or due to values and beliefs that are not consistent with the reform.

Both the technical and cultural dimensions of reform must be addressed. In fact, major progress on either one may be difficult without simultaneous progress on the other. The situation must be viewed as a system; everything connects to everything else. Change usually requires simultaneous attention to a number of factors.

As noted earlier, achieving the desired reforms demands great effort and commitment expended over a substantial period of time. A major reason is the concomitant changes in values and beliefs which are a part of the process. Particularly noteworthy is the elapsed time generally required. These changes in beliefs and values generally occur in the context of exploration and trial of new ideas and practices. This is the aspect of reform that is both most difficult and most important. One should not expect it to happen quickly. Assume that any significant change will take an extended elapsed time; any efforts for promoting change should be based on this assumption.

These attempts at change should also be expected to result in significant tensions for the participants as they wrestle with their values and beliefs. These tensions result in what we have labelled dilemmas. As they attempt to shift from traditional to reformed educational practices, teachers face many dilemmas that are not quickly resolved. Some of these dilemmas are pragmatic and logistical matters; most are grounded in the values and beliefs which are under scrutiny. Whether teachers, administrators, or parents, resistance to change commonly is grounded in values and beliefs about education that are in conflict with those in which the reforms are grounded. Some examples may be helpful.

The textbook issue revisited. It was noted earlier that the lack of a prominent role for a textbook in reform classes creates a dilemma for many teachers. Although it commonly is at least partially rooted in the practical matter of how to teach in a manner that does not depend on a textbook--the technical dimension--the tension for many teachers is more a question of their conviction that learning from a book is inherently valuable. It is an indication of their values and beliefs regarding learning.

Although I am not sure how well understood it is by the teachers themselves, as an outside observer I am persuaded that the differing opinions about the textbook reflect differences in persuasions about how a class can best be conducted to aid student learning. The extent to which teachers see knowledge as something for students to acquire versus conceptions that they must construct is reflected in their comments.

Two teachers expressed the belief that not all students learn in the same manner, and that some students may be helped if they could read about science concepts. Other teachers did not want the textbook but felt that a set of science resource books would be helpful.

Views of assessment. Another area of tension concerns assessment. While teacher dilemmas related to *classroom* assessment are connected mostly to the technical dimension, matters of large-scale testing are more in the cultural dimension. Many teachers are not only convinced that it is important for their students to do well on standardized tests used for educational assessment and admission to college, but they are convinced that they measure important understandings. At the same time, it currently is becoming more apparent that developing large-scale performance assessments that are reliable and valid is costly and difficult to implement. Thus, the large-scale standardized tests their students will take generally give inadequate evidence of being consistent with the reforms. Still, many teachers are concerned that the reforms they are being asked to implement will not fully prepare their students for the assessments they will face, as illustrated in the following cases.

Ultimately, teachers felt the SAT hanging over their head as a measurement on which their students had to be successful.

Their perception was that the [state] test did not match the SPRSE curriculum. In response, some of the teachers suspended the reform program and taught lessons from old textbooks for several weeks. They were concerned that their names would be published along with their student test scores.

Most teachers were keenly aware of the standardized tests which students had to be prepared to take as college bound seniors and in the upper level classes there was a reluctance to turn the agenda over to conceptual understanding entirely ... This pull between beliefs about the place of computational expertise and conceptual understanding in a presumed hierarchy of mathematical knowledge reappears throughout this study, whether in curriculum, assessment, or choice of materials.

For some teachers, their fear is that large-scale assessments will not change to match their new teaching approaches and classroom assessments. While there is research on this topic that should be comforting to such teachers--in that, it indicates teaching for understanding is good preparation for extant types of tests--it is not widely know among teachers.

The preparation ethic. The learning goals of the reforms are problematic for many teachers. They are committed to the "preparation ethic," the idea that the accumulation of fairly discrete knowledge and skills, rather than critical thinking skills, will prepare their students best for the next level of schooling. The big concern is often what they will "need to know" when they get to college--or in the case of middle school students, when they get to high school. Concerns about "coverage" often get in the way of teaching for depth of understanding, integration of content, and pursuit of the major themes of the content. Many of the mathematics teachers in our cases, for example believe that traditional mathematics has served their college-bound students well. Similarly, many science teachers question how well the "new" science will prepare students for

college, as illustrated by these comments from Betty, a teacher who is quite firmly committed to the reforms.

> They have balanced some equations, but the chemistry teacher in me still wants to see a whole unit on stoichiometry where, you know, they have balanced a whole lot of equations and they have gone through mass conversions and mass mole conversions. And because I know they are going to have to do that in college, and I guess I would feel more confident that the kids would be successful if they had to do more of that stuff here.

Betty is torn between this concern for her most able students in their future college careers, and the more middle of the road students who may succeed in the future in a way they would not have if they had been restricted to lower level tracked courses.

These illustrative teacher dilemmas are largely rooted in beliefs and values that are to some extent in conflict with those of the reforms. They also are related to a school culture that expects certain roles for students and particular forms of student work. To a large extent these roles and work are different than those promoted in the reforms. They clash with the school culture also because they demand a new level of responsibility for students--an independent responsibility often feared in the current school culture. Students need to be given a bigger part in developing this new role and definition of work expectations. The tension experienced by teachers has both technical and cultural dimensions. If students were not actively involved in defining their new role, another tension was present:

> ... the tension that occurred in math classes when teachers attempted to allow the process to focus on the student as constructor of their own knowledge without actively engaging students in the transformation from passive learner to active learner.

Resolving such tensions requires considerable work on the part of teachers with their students in teaching them new roles and helping them define new forms of intellectual work.

The key means for teachers to make progress on resolving such dilemmas is through collaboration with fellow teachers in the day-to-day school work context. It can have a powerful influence on teachers' values and beliefs as well as facilitate change in the technical dimension. This topic will be addressed again in our later discussion of the essential ingredients of a reform setting.

The Essentials of Attaining Reforms

Having described the nature of the reforms sought and the barriers to their initiation in our cases, attention can be turned to how barriers were overcome and the desired reforms actually put into practice. What are the essential conditions and necessary actions for reform to be attained? They are the central focus of the case studies and worth careful consideration.

The cases through which these questions are being addressed are ordinary "real world" school settings, not special "show case" schools. As is probably already apparent in the case

descriptions, the desired reforms in these cases have not fully developed into their ideal form throughout any of the sites. Furthermore, one should not expect to have such sites to study. The results of our thorough process of seeking out very successful cases are an indication of the paucity of "picture-perfect" reform settings. Other research confirms (e.g. Anderson, et al., 1992; Fullan, 1991) this picture of reform. It is a long term process--possibly one that is never fully completed. The expectation probably should not be to study fully reformed sites; the orientation probably should be to look at any particular reform site as being a certain distance down the reform road and a source of insights for others considering taking this path.

Having made this point, however, our cases still have much to offer in answer to the question about the essential ingredients for attaining significant degrees of reform. The situations found across the nine sites are quite varied, but there are some common key messages that emerge from the cross-site analysis--both in terms of successful components that are present, as well as components whose importance is apparent by their absence.

A key result of this analysis is an unequivocal statement that there is no "silver bullet." At successful reform sites, attention is given--sometimes without conscious proactive political decisions--to all of the dimensions: technical, political, and cultural. A systemic perspective is of great importance and care must be exercised to see that no important factor is ignored. The search should *not* be for the *one* key ingredient; the search should be for the inclusion of *all* of the essential ingredients--and putting them together in a manner that takes full account of the systemic nature of the situation.

The technical dimension. At least at the local level, this is the dimension to which people initiating reform give primary attention. The desired curriculum materials must be developed, acquired and/or adapted; teachers must learn new approaches to instruction. Mechanisms typically are established for facilitating these changes; working groups are set up to deal with curricular matters and inservice education is provided regarding instructional approaches.

Mechanisms for collaboration. An essential ingredient of reform sites is a context in which teachers have the opportunity to collaborate with each other on the work of instruction. While important in the cultural dimension as well, attention here is given directly to the technical. In these collaborative working environments, teachers receive both curriculum and instructional help from each other that often is of high importance. Collaborative work situations may be the most essential reform ingredient as indicated by these descriptions from three different cases.

> Key to constructivist learning for students is the need to communicate as they work through the process of scientific problem solving and inquiry. Important to consider here is that as these approaches are necessary for student learning, they are also critical to teacher learning ... For both students and teachers in this science program, the social construction of knowledge through cooperative and collaborative interactions appears to be critical to overall learning ... The teachers view their working together as "invaluable" to their success at implementing the program.

Leadership is essential to establishing a process of teacher collaboration, but it is through the teacher collaboration itself that much of the important reform work occurs at Westview. This process creates communication among teachers in the context of their collaboration on developing materials and in making plans for their classes. Fundamentally, it may be the most powerful force for change within the science department. Outsiders to the department (e.g., the principal, other department chairs, and district leaders) tend to emphasize Karl's leadership when talking about the origins of the science education reform in the Westview science department. Insiders to the department (i.e. the teachers) tend to emphasize communication and collaboration with their peers as the basis for what they were doing. As Dave put it when asked how important collaboration was to what was happening within their department, "Paramount. I mean it has got to be the most important thing that we do, we all work together on it, we all have input on it, we're all communicating almost on a daily basis." ... Teachers are very aware that they have acquired a larger pool of ideas as a result of this sharing. In addition to this very specific sharing of knowledge and insights, there is a motivational factor as well. Another word that is used in describing the benefits of this collaboration is "support".

We looked at how the three teachers constituted a learning group as they worked together as a teaching team. They had created among themselves strong and positive communication patterns. They indeed drew in knowledge from outside the group both in terms of interesting materials that could be used in the class, research ideas about instructional techniques and knowledge about their own group of students and the context of their school. They had creative planning sessions where they generated new ideas of how to teach. They created a trusting atmosphere in which they could take risks to try new instructional methods ... They were not worried about the principal or some other person evaluating them on the quality of their work ... A very positive characteristic of the Core team was the way in which the teacher functioned as a "learning community" among themselves.

Conferences and networking. Less systematic learning contexts are important as well. Many teachers cite attendance at conferences and related informal networking as being very important. At many sites, such activities are both valued and supported in overt ways. Contact with the "outside" is of significant importance.

... the network of support that they developed outside of the school was crucial to their continued emphasis on trying new ideas in the classroom ... Teachers attended conferences and workshops because it was encouraged as a part of the culture of this department.

Teachers also see the benefit of the regional SS&C activities in terms of the interactions it provides for them with other teachers from other schools. There are meetings where, "People have been able to get together to talk, to get ideas and maybe even to find out that some of the things that you are doing aren't totally off the wall. I mean, when you are developing something new you don't know quite where you stand on the spectrum of things, and I think that's a real important part of the program, is the networking."

They openly learned from one another and were eager to apply new ideas that they acquired through outside conferences and other sources.

Inservice education. Inservice education was an essential ingredient of the reform settings. Although not limited to the technical dimension, this inservice education was crucial to communicating new knowledge and skills related to curriculum and new pedagogical approaches. It addressed important aspects of the role of textbooks in the classroom, the nature and role of assessment, the use of group work, the teachers' role, the students' role, and the nature of the

work done by students. All of these matters are important--and obviously highly interrelated--and require ongoing attention.

The most valuable form of this inservice education seemed to have a lot in common with the form of education advocated for students in the schools.

What seemed most valuable to teachers during the in-service sessions were the opportunities they had to talk with other teachers about the problems that they were experiencing and to hear about the solutions that other teachers were employing. As students in this science program problem solve and create and answer questions in cooperative group settings, likewise teachers "construct" their own knowledge through conversations with their peers.

An indicator of the importance of the inservice education was the impact of its loss in several instances some years into the reform process. It was noted in case after case, as illustrated below.

It cannot be said, though, that three years of staff development necessarily provided enough support to bring all teachers to a place where they can successfully implement this innovative curriculum.

This problem is especially acute for teachers new to the school and to the reform program. As they struggle with a new curriculum and a new way of teaching these teachers have no peer support, no one at the school to help them resolve the nagging day-to-day problems. One of the teachers implementing the reform program verbalized her feelings of being "on her own," except for some moral support.

Efforts sustained over time. As just noted, there is a tendency at reform sites to give these matters concerted attention for a year, or two, or three, and then assume they have been addressed and no longer need ongoing attention. This outlook generally is a mistake. Reform requires the acquisition of a substantial amount of technical competency on the part of teachers. The task takes longer than generally thought, different people start the process at different times, and it takes differing amounts of time for the participating individuals. Furthermore, it should be recognized that the task never ends because the school--viewed as a system--is never static--there is continued turnover of personnel, for example--and there will always be an ongoing need for assistance on the technical dimension.

Arrangements that allow for teacher collaboration on a continuing basis are essential. There are a variety of means by which such collaboration can be fostered, but there are forces that tend to restrict such support for reform as illustrated by one of the science cases.

Ideally, the teachers would like to have multiple sections of a given year of Coordinated Science (e.g. first year Coordinated Science) occurring in the same class period and have the same planning period for all of the teachers teaching a section of this particular year of Coordinated Science. Such an arrangement has two very important outcomes: (1) it facilitates team teaching and (2) it gives them the common planning period that is so important for developing communication and teamwork. What seems to be a relatively easy matter to accomplish apparently is resisted by the administration and counseling staff because it significantly reduces the options available to students in creating their individual schedules.

Fostering new student roles. Fully successful work on the technical dimension must include close attention to the new roles played by students in a reform context and the new forms of student work they must produce. It is the "bottom line" that is at the core of quality work within the technical dimension. Yet in our cases, it was the central element of the total situation that most often was missing.

It was not always apparent to teachers that the reforms they were pursuing demanded such a distinct change on the part of their students, and even when they were conscious of the need--or at least thought it was worth testing out--they usually were not sure how to do it. Although we did not systematically check the agendas of the inservice education provided to the teachers, we got little indication that substantial, direct, "how-to-do" help was provided to teachers on changing students' role and work. What was provided tended to focus on some limited aspect of instruction, e.g., conducted laboratory work in science in a more open-ended manner, rather than focus on the entire instructional process in a holistic manner.

The political dimension. There is a tendency on the part of some persons to think of the political dimension largely in terms of the actions taken by elected officials--from local school board members on up to the federal level. Although there obviously are many important actions taken in these arenas, the political dimension is much broader and includes much that happens within a school itself, as well as the school district and the community. In fact, local actions distinguish the successful reform sites from other schools.

National and state influences. To say that these distinguishing features are at the local school level is not to say that what happens at higher levels is unimportant. In fact, they may be crucial. We return again to the systemic perspective and note that while these actions at the higher levels may be far from sufficient for reform to occur, they may well be essential. Westview is a good case in point. The success of their reform was largely due to visionary leadership by the science department chair, but the leadership probably would not have been exercised in the directions it took without the focus set by state curriculum guidelines and national reform documents.

Another example is provided by a mathematics department where, over a period of more than 15 years, the department has been influenced by national movements in mathematics education as leading teachers have attempted to respond to these movements toward reformed mathematics.

> Outside influences that led to current practices included teacher attendance at national conferences, service by teachers on state advisory boards, administrative support, and grant monies.

In addition to the vision provided by these national movements, federal monies have played an important role as well, as illustrated by the science site that adopted a set of curriculum materials developed with the support of NSF funds.

Critical to this reform effort was national funding that enabled program developers to write the innovative curriculum, that provided the district and teachers with staff development and with on-site support from the university science site-coordinators and staff, and that provided students with science materials and equipment. Without this initial national funding, this particular reform effort would not have taken place in this district.

In addition, some resources have come from the national and state level to other sites, through such means as grants. While very helpful, however, one does not gain the impression from reading most of the cases that this supplemental funding was a deciding factor, with the exception of cases where initiation of the reform hinged upon new curriculum materials that had been developed with federal monies. Even here, however, one cannot be sure that the local leaders would not have sought out other reform-oriented materials that had been developed without such funding.

Local leadership. Local leadership is a key ingredient in these successful cases, whether that be at the department or school level. In case after case, the mark of these local leaders is striking.

In instances where the reform was at the department level, especially in cases of senior high school science or mathematics reform, this leadership generally was from the department chair.

The educational reform environment fostered by state level activities is crucial to what has taken place at Westview High School, but the true driving force in this particular case is Karl Tozer, the department chair. Without him, what has happened at Westview would not have happened.

In such cases, however, the leadership of the principal also is important, if in no other way than supporting the department chair in his or her efforts. In cases of school-wide reforms, the leadership of the principal is absolutely essential. Given the nature of the reforms sought, the style of the principals in our cases seemed especially important as illustrated by the perspective of the following principal.

Ideas must come from others. A principal needs to do more seeding than leading. People have to own the ideas. I guess you could say I planted seeds early on.

Principal leadership that empowers teachers is illustrated by yet another case.

Teachers feel trusted by the administration to do what they believe is best for students. Even the evaluation process that teachers go through for their first three years in the school is viewed as supportive rather than threatening. Two main reasons for this tone of support appears to be the philosophy of the administration and the vision that bonds them.

The most successful of these leaders--whether department chairs or principals--are effective in keeping a focus on an understandable vision for reform, removing impediments to action, getting resources and fostering a climate of collaboration among the teachers involved in the reform endeavor.

Teacher empowerment. Teacher empowerment is characteristic of these successful reform settings. While vision communicated from a higher level may have been important, successful reformers--whether individual teachers, a department or an entire school--had the autonomy and power to determine how they would put this vision--or some modification thereof--into practice.

This empowerment of teachers enables them to grapple with their values and beliefs related to the reform agenda, and the new practices that are under consideration. Personal engagement with basic educational issues is at the heart of the change process for each individual. Commitment to the reforms on the part of teachers demands values and beliefs different from those generally held by teachers. In successful reform settings, teachers have numerous occasions to confront these matters.

In other words, teacher learning is central to educational reform. Such learning occurs most readily in contexts where teachers have the power to grapple with their own vision of change and how to initiate it.

Public support. This engagement with new values and beliefs is at the heart of yet another aspect of successful reform settings. The public--particularly parents in higher socio-economic communities--must also grapple with shifting values and beliefs about education. In some manner, school personnel in successful settings have acted to defuse public concerns about controversial matters, bring parents into the deliberation process, and/or provide options for students that give parents a choice about whether or not their children will participate in at least some aspects of the reform. In cases where parents have been more engaged in the decision-making process they have had more opportunity to confront their own values and beliefs, a step that may by essential to long term educational reform.

Fairness and justice. An obvious characteristic of the reform situations portrayed in these cases is their commitment to equality of opportunity for all students. This form of fairness--defined at least partially by the absence of tracking and ability grouping--is typical of these cases. The presence of this characteristic is what one would expect in these cases; after all, they initially were selected partially on that basis. As noted earlier, however, there is some debate about such characteristics in some cases; it is the basis of some conflict.

The means of addressing such conflict in most of these cases--at least in the professional context--is rooted in collective decision making. While such conflict resolution often is viewed as a political matter, it also clearly is a moral issue as well. Given the connection of such conflicts to people's values and beliefs--and the long term personal reappraisal involved in their change--fairness and justice demand extensive participation of these professionals in this process. These sites generally appear to display fairness and justice in this additional regard.

This fair and just professional perspective is apparent in many of these cases in more than the formal means of decision-making; it is an integral part of the teacher collaboration that is so

characteristic of much in these cases. Because this collaboration addresses the basic educational issues of the workplace, is intertwined with teachers' values and beliefs, and provides a personal context for addressing them, it is part of what it means to be authentically human; it is a moral aspect of the cases. There is fairness and justice for the professionals involved as they work in a context which fosters continued learning and professional development.

Finally, the focus of these reform programs on learning for understanding, integrating such understandings and developing higher order thinking abilities, is more fair and just than the focus of programs with limited educational goals for students. Thus, in terms of student outcomes sought and attained in these cases, fairness and justice again can be said to be essential ingredients of the reform sites.

Summary. The political dimension is highly complex; it has many facets which are very interrelated. An appropriate set of actions--operating in a systemic manner--can have a major influence on educational practice and be crucial to significant reforms. In successful sites there are indications of policy alignment, i.e., the various political levels are headed in the same direction and their policies complement each other.

On the other hand, there is little indication from these cases that policy alignment and having all political entities moving in the same direction will insure that reform will occur. An appropriate systemic mix of political influences--including resources--is a necessary, but not sufficient condition for educational reform. There is another dimension--even more basic--that in addition to the political must be addressed. In successful sites, matters that pertain to the cultural dimension are key elements in the total reform picture.

The cultural dimension. Reformed education is characterized by students occupying new roles and doing new forms of work. These new roles and forms of work for students, in turn, are the result of teachers occupying new roles and doing new forms of teacher work. While these new roles and practices on the part of teachers are influenced by matters in the technical dimension, the cultural dimension is central to the changes. A re-examination of basic educational values and beliefs is at the heart of reform for professionals.

Effective education for reform must attend to more than the technical dimension; it must put the cultural dimension front and center. While it is clear from these case studies of successful reform sites that the cultural dimension is central, the best way of addressing this dimension is not obvious.

Inservice attention to values and beliefs. Generally, the cases do not detail the inservice education in a manner that makes clear its contribution to re-assessment of these values and beliefs. It appears, however, that inservice education can play an important role in this regard.

Recognizing the importance of teacher beliefs on practice, WSU has constructed a two-week summer institute and follow-up procedures that address teacher beliefs. The purpose of the institute is as follows: * change teacher behaviors, * reduce teacher isolation, * decrease the rate of recidivism (return to the old ways) ... The staff continues to monitor teachers' beliefs periodically during the two weeks of the institute while at the same time engaging the teachers in the following activities structured to change their beliefs: * activities, structure questions, and discussions which emphasize dissatisfaction with the traditional science activities, * continue to compare traditional teaching with project teaching.

For one particular teacher, it seemed evident that the in-service provided an opportunity to reflect on long-held beliefs about student learning ... In contrast, though, another teacher, Andrew, describes the difficulty he had with learning the new approaches and understandings associated with this program and how the staff development and in-service sessions were rarely helpful in making a shift from old teaching approaches to new.

Collaborative influences on values and beliefs. While the role of formal inservice education within the cultural dimension is not sharply defined, it is clear in our cases that collaborative working relationships among teachers provide a very important context for the re-assessment of educational values and beliefs. In this context--where the focus is the actual work of each teachers' own students--one's values and beliefs are encountered at every turn. It is a powerful influence. The reforming teachers in our cases did not do their work in isolation; they worked together with fellow teachers in their team or department. Crucial reform work takes place in this context.

It also is important to note that this work needs to extend over a long period of time, as indicated by the experience of one middle school science teacher.

Andrew was unsure about the benefits of the program and was hesitant to implement the curriculum in his classroom. It appears, though, that after four years of field testing and implementation, Andrew has come to a critical place. He now sees the differences between his belief system and instructional strategies and those of the reform and he perceives that further training in this key aspect of the program would be of great value to his teaching. Therefore, it is critical when implementing reform to consider the length of time teachers may need to reach dissonance with their long-held beliefs and approaches.

As noted frequently above, reformed education results in new roles for students and a focus on new forms of student work. While not all of the cases were equally successful in this regard, it is clear that these changes are at the heart of successful reform. While resistance to reform on the part of teachers, administrators and/or parents generally has been encountered, in successful sites it has been addressed appropriately. Such resistance is grounded in values and beliefs about education that are in conflict with those in which the reforms are grounded. Thus, the cultural dimension highlights what may be the most important of the essential ingredients for educational reform--direct attention to the values and beliefs underlying the educational process.

Extending the Analysis Along Lines Suggested by Other Research

The cross-site analysis presented above grows out of the case data itself. Close examination of related research may suggest ways in which the analysis could be extended to see if the case data

has additional insights when examined from the perspective of this other research. Two key areas having this potential are the focus on the power of teacher collaboration in the work setting and the need for a redefinition of student role. Rather than extending the data analysis in this regard, however, they are given further attention in following sections on Implications for Policy and Practice (in the case of teacher collaboration) and Implications for Needed Research (in the case of student role redefinition).

A topic deserving of extended analysis is the systemic character of successful change endeavors. If we are to apply systems thinking to curriculum reform, it is essential to understand what it is, its applicability to educational situations and how this thinking can inform educational change endeavors. Its power is great and it fits the situation. There are various ways to characterize systems thinking but because of the potential power of his models, attention is directed here to the characterization of Senge (1990). The Senge conceptions were first used in this project in 1991 when designing the research. Explanations of its relevance to understanding educational reform is provided in a literature review produced as part of the project (Anderson, et al., 1994). The reader is referred there for elaboration of the ideas of systems thinking, systemic structures, systems complexity, and a learning organization. Because the ideas are developed in this literature review--and of course, in Senge's book itself--they are not elaborated here.

The appropriate application of systems thinking to educational reform is *not* in finding the solutions that will solve the problem in a given setting. The situations are too complex and achieving success is an art. Systems thinking is an aid to this art. It can help in understanding the dynamic complexity of a given situation, pinpoint key interrelationships, and help anticipate the unintended consequences of proposed actions.

Systems archetypes. A specific tool used in systems thinking is the application of what Senge (1990) calls systems archetypes to a given setting to identify key interrelationships. These archetypes are an aid to seeing interrelationships within the whole. Their purpose is to help identify structures, locate the feedback loops and find the leverage, something that is hard to do in the midst of the crosscurrents and pressures of real-life situations. We use them here to understand more completely the results of our cross-site analysis.

Of the ten archetypes Senge describes, three appear to have particular relevance to the situation portrayed in our cross-site analysis: "limits to growth," "shifting the burden," and "growth and underinvestment." A summary development of the application of these archetypes to this cross-site analysis is presented to show their relevance and potential.

Limits to growth. In this archetype there is a period of accelerating change which then meets resistance. In an educational reform context this resistance may come from professionals who are *forced* to make changes they do not want to make or from parents who do not want the new form of education for their children.

The principle to apply for overcoming the dynamics described in this archetype is removal of the source of limitations. In the case of the educational reforms portrayed in our cross-site analysis, such actions could include:

1. Gaining the support and participation of resistors among the professionals through more and/or better inservice education and, more importantly, creating a work context that is more encouraging of collaborative working relationships that have the potential of fostering the desired changes in values, beliefs and roles.

2. Provide better education for parents and opportunities for participation that will develop both understanding and ownership.

3. Take practical steps to reduce the time demands on professionals, such as through purchasing curriculum materials rather than having teachers develop them as part of the reform process.

Shifting the burden. In this archetype, fundamental, long-term actions for reform are neglected in favor of those with more immediate, and probably ephemeral, results. In an educational reform context, this approach may result in focusing on new activities for teachers that have to do with new curriculum materials, new forms of assessment, and new teaching techniques without getting to the basic issue of helping students develop a new role for themselves.

The principle for this situation is to focus on the fundamental solution, i.e., re-negotiating the role of the students. Inservice education, collaborative teacher projects and other actions need to focus on this fundamental issue.

Growth and underinvestment. In this archetype, growth approaches a limit due to under-investment in additional "capacity." Underinvestment appears to pertain to our cases. Inservice education often was terminated too soon. Inadequate steps were taken to create a climate of collaboration in some cases. Not enough teacher time was invested in helping students re-negotiate a new student role.

The principle for this situation is to hold the vision and invest what it takes to make it work, such as more funding for inservice education, changes in course scheduling to provide more time for team planning, and more teacher investment of instructional time in helping students to acquire a new role.

The future. Systems thinking is an important key to understanding and effecting educational reforms. All dimensions--including technical, political, and cultural--must be addressed in a systemic manner with recognition of their interactions. Explanatory models--such as the Senge archetypes--offer assistance in understanding these dynamic relationships and guiding administrative and policy decisions about reform.

ASSESSMENT OF THE OUTCOMES OF THE REFORMS

Reform is a long-term process and the sites studied are in various stages of that process. Consequently, the outcomes of the reforms vary as well. In general these outcomes are for students and teachers, although there also are outcomes for administrators, policy makers, program developers and parents.

Outcomes for Teachers

While the major goals of these reform efforts concern students and their learning, at this point in the majority of reform sites, teachers experience the greatest apparent influence. Teachers are grappling with three areas of change--1) generating constructivist learning among students, 2) developing the role of facilitator, and 3) assessing in meaningful ways the constructivist learning of students.

Generating constructivist learning among students. More commonly called constructivist teaching, the process of generating constructivist learning among students is not clearly mapped. Teachers must develop processes that encourage students in their quest to construct understanding. Teachers are actively constructing what it means to teach.

To actually do so--whether developing approaches from scratch or using existing curricular materials in final or field test form--requires that teachers rethink and reconstruct their approaches to teaching as well as their understanding of their subject matter. They often must learn new techniques that are a odds with their own education and experience.

At many case study sites teachers were grappling admirably with various elements of the process, be it understanding and using new instructional approaches or understanding subject matter in new ways to assist students in asking the questions necessary to get "unstuck". But the intersection of teacher beliefs and new practice is also the greatest hurdle in all sites, as some teachers are more primed for the change than others. Their paths out of their individual quagmires differ, but as with students, these processes need time and effort to develop.

Each teacher at each site is at a different place along the continuum to constructivist teaching. As is evident in each of the cases, teachers have moved varying distances from where they were when the process began. Some saw mostly frustration and inner conflict, while others experienced major successes in changing their teaching.

Developing the role of facilitator. Unlike many reform efforts that came before, constructivist teaching and learning requires extensive teacher growth. This growth generally includes identifying existing beliefs and examining the congruency of these beliefs and the reform's goals and purposes. These processes occur in the teacher's active use of the new role. Because this new role is so tied to teacher beliefs and identity, it is probably the most difficult aspect of

constructivist teaching to embrace. Again the observed teachers are making strides. For some it is learning the name of a process that is a part of their existing practice, even if in rudimentary form. For others it is more effectively stepping back or letting go. For others it is refining questioning techniques or developing better tasks that elicit and encourage student learning. Teachers are developing new roles incrementally in some instances, and by leaps and bounds in others.

Assessing learning of students. Most teachers have not yet fully developed a process of assessing their students' learning from a constructivist orientation; many have only a glimmer of a vision of the personal development they need in this area. Teachers see new forms of assessment as a natural outgrowth of the changes they are making in student learning and many teachers are slowly trying and testing new approaches. Outside forces, however--in the form of program developers, policy agents (e.g. legislators)--are accelerating teachers' developmental time line. This pressure is exacerbating the tension between many teacher's learning and practice because the new assessment approaches do not easily fit their traditional classes or their traditional thinking. As with the development of other aspects of constructivist teaching, teachers are learning to generate, use, and score new types of assessments. It is an additional dimension of teacher learning.

Where these new assessment practices intersect with student grades, they generate new concerns for teachers, students, parents and administrators. Simple knowledge was much easier to assess. From years of precedence and practice, traditional paper and pencil assessments generate reliable, valid and generalizable results. The new authentic, context-based assessment of skills, knowledge and process--while potentially more valuable--are unfamiliar. More about this aspect of reform outcomes will be discussed below under Outcomes for Second Tier Change Participants.

Outcomes for Students

Students are impacted by these reform efforts. Exactly how and to what extent they are impacted may require studies of a more longitudinal nature. However, the outcomes for students are at least fourfold:

1. more students are engaged in significant learning of subject matter and frequently for a longer time;

2. students are developing and practicing thinking skills;

3. students are experiencing those skills in an embedded, applicable context, which will provide more direct transfer to their future lives and work; and

4. students are developing a new role as life-long, self-directed learner.

More students exhibit outcomes. The reform efforts are targeted for all students. In the high school level, case studies indications are that students not previously well served by traditional programs in science and mathematics are succeeding and enjoying the reform classes so much that they are electing to continue in the programs after they have met high school graduation requirements. They feel a confidence not demonstrated in previous learning situations and are doing more intellectually. This outcome is documented by increasing numbers of sections of most reform classes. So students are learning more by participating over more years.

Quantitative data demonstrates that students do as well, and in some cases better, on traditional tests at these sites.

Students exhibit thinking skills. Changes in the learning process have led to different assessments. Students are now asked to demonstrate the fruits of their new classroom role by presenting their knowledge in multiple formats and measured against new criteria. Teacher growth in the development of rubrics to define standards for these new assessments is important for clarifying expected student outcomes. Where students have clear understandings of the standards--e.g. quality work, synthesis of knowledge and skills--student outcomes are impressive.
The nature of these assessments make traditional quantification difficult. At present in most reform sites students are doing as well on traditional assessments as they have in the past and are doing better on open-ended assessments than students in traditional programs. As practices become more refined, more and better ways to view assessments and report their results will also evolve.

Students experience contextualized learning. The "less is more" theme, coupled with integrated content embedded in contexts familiar to students and with practical applications, not only teaches knowledge, process and skills, but also mirrors for students work place skills of communication, problem solving, quality work and cooperative effort.

Students become life-long, self-directed learners. While it is hazardous to make predictions about life-long changes, there are clear indications in the present of students who are becoming self-directed learners. Students who have participated in change efforts over multiple years generally report positively about their experiences, learning and gains.

Outcomes for Second Tier Change Participants

Parents play a critical role in the continuation and longevity of a reform. When brought aboard the process early, they often are the best of support networks. When threatened by the changes they are left feeling helpless or angered. The reaction is to return to the old practices. As with professionals, they need to be educated and kept informed at all stages of the reform to remain allies and supporters.

An assessment of outcomes suggests that the reflective nature of the change process requires simultaneous learning at many levels. As seen here teacher learning occurs first and is greatest at most sites at this time. Students are next because of their proximity to teachers and their role is the true focal point of the process. Administrators, school personnel, program and staff developers and parents also are major players. The orchestration of this process is delicate.

ASSESSMENT OF RESOURCES REQUIRED TO IMPLEMENT THE REFORMS

Implementation of reform is dependent on several resources including money, materials, time, and ideas. Ideas about reform are generated in many quarters, but for an actual reform to occur an initiator must begin the process. The initiator of the reform effort and his/her position relative to the source of these assets is a key element in the process of reform implementation and continuation. Frequently the initiator and the source of assets are the same entity, usually an organization, occasionally a person. The resources of reform are discussed here in terms of initiators of reform and sources of money, materials and time.

Initiators of Reform

A variety of groups and/or individuals were instrumental in initiating the reform efforts studied here. While all of the mathematics reforms, for example, are traceable to the NCTM Standards, in one site it was the efforts of a single teacher/department chair, and later her disciples, that began and is continuing the chain of events that culminated in the program at her school. At a second site, a cadre of teachers, through individual and group efforts, initiated a curricular reform, first through a series of textbook field tests and adoptions and then through the development of an original curriculum. At the last math site, a federally funded, state-developed curriculum was field tested as part of teachers' new conceptions about mathematics teaching and learning.

District level administrators initiated two of the science case reforms. In both cases, universities studying and/or developing pilot materials sought field test sites. One school was specifically solicited because its faculty members were known at the state level as leaders in reform. The reform initiator at the third site was a teacher/department chair who was also known statewide for his leadership in reform.

Reform in thinking across disciplines is demonstrated in the cases at all levels of initiation. At one site, the district level administration along with community members sought a broad-based change which resulted in principal-teacher alliances at one school that created a demonstration program in history emphasizing higher order thinking skills for all students. The state, through sweeping legislation, pushed an already reform-oriented school toward greater reform efforts at a second site. The third site demonstrates the vision of and mentoring by a principal in school-wide reform that best conceptualized in a unusual interdisciplinary thinking skills program.

Sources of Money, Materials and Time

A hierarchy of sources. The hierarchy of financial and material resources begins at the top on a national level. In most educational reform, especially in mathematics and science, the National Science Foundation is a key source of much of this reform money. The US Department of

Education is another money source. Many states have entered this arena as well with money and regulations.

Governmental bureaus, federal and state, generally funnel their monetary resource through various agencies. In the reforms studied here these agencies include independent program developers, universities and colleges (individually or cooperatively), and districts. In some cases, federal money is channeled through state agencies and then to one of the middle level sources.

What is passed on to the schools from this middle level may be money but also may include curriculum materials, assessment materials, technology, content and/or pedagogical information, knowledge and skills--and time in professional support, staff development, and inservice training.

Within the school, teachers--individually or as members of a department, an interdisciplinary core or organizational family or the school as a whole--generate and solicit resources of money and materials. They are the premiere contributors of time.

Source patterns in curriculum reform cases. In three case studies--two in science and one in mathematics--funding originated at the federal level with NSF and US Department of Education funds. In each case the funds were funneled through different intermediaries. One NSF grant tied an independent program developer with a university and a district to support teachers field testing a reformed curriculum. In another NSF grant, two universities were networked with a district and school. A third NSF grant funneled money through the state, its university system and the district to the school, gathering additional funds for the project at each level. In general these funds supported curriculum development, teacher training, materials for field testing, and various support services between agencies. Individuals at the sites may or may not have had much in the way of administrative support. A critical time in these sites is when the field test is over and the district and school face the financial and curricular concerns of adoption. At one site the administration did not maintain the modem necessary for program developer support to teachers after the first year of the multiple year testing. In two sites, inservice and teacher training was all but eliminated at the end of the field test, despite teacher needs for continued pedagogical understanding and practice with curriculum and assessment.

One state, through its legislation, has initiated the reform, but has primarily placed the burden of resources on the schools. In this site the district, school, principal and teachers have born the brunt of the funding dilemma through innovative grants, special partnerships, private foundations and a reallocation of existing funds. In this instance as well, the need for appropriate inservice education, although legislated, was not adequately fulfilled.

In one case, the public relations ability of the principal--as well as the community's and district's vision--has fostered reform through with several state funded demonstration programs. These

funding sources are an outgrowth of the district led reform in thinking skills, itself financed primarily through district budget allocations. So in this case, the funding pattern is reversed. The district adopted an outcomes-based philosophy and now at least three programs within the study site have been funded by the state as innovative models for other schools. One of the three state-funded grants was for the thinking skills program researched here. Inservice and collaborative interaction is continuing especially under the guidance of the principal and several trainers in the building.

At the school, department and teacher level funding is less readily available. Two case studies were of programs in new schools founded on innovation. The reform leaders in both situations creatively approached the needs and costs of reform. At one site, the funds allocated for textbook purchase financed not only the black line masters and their photocopying of the purchased curriculum but also numerous resource books, manipulatives, classroom sets of graphic calculators, and at least one trip to the curriculum developers for training.

In the second instance, a building decision was made not to hire department chairs and instead to divide the duties among department members with a small stipend per task. To institute this alternative management style a waiver in the district contract was negotiated. The $15,000 savings provides a common pool for professional development time, special assignments, and curriculum development work to name a few. The learning organization qualities present in this environment are a critical element in the evolving innovation at this site.

At the department level, several factors are important in generating funding--a common vision, culture of collegiality, willingness to do necessary ground work, and clear rationale. In one instance, a team of math teachers built a long history of innovation by volunteering for field tests of products they believed served the needs of their students. They pursued technology before its use was common in schools. With that history they applied for district funds for innovative programs and foundation grants for teacher growth initiatives. They collaborated with businesses and the State Department of Education to build a new program complete with teacher training. Another grant purchased "hardware" for their classrooms--graphic calculators, televisions, VCRs, storage cabinets, new tables and chairs for students, and high back chairs for them. These teachers were treated as specialists by the building principal and district curriculum director, both of whom "found the dollars" to support various reform projects within the department.

A leader having the knowledge, personal skills, organizational skills, ideas, persistence and respect of peers and administrators is a resource in himself, especially when this vision is clearly aligned with the state's curricular framework and professional organization recommendations for integration. In one case much of the reform resulted from the hard work of a department chair and collegial interaction of this person and the teachers. In addition to financial support for materials and personnel time, the building administration provided endorsement and advocacy; building level funding was enhanced by some district and state funding.

Resources Required to Implement Reform

As evidenced in the specific sites discussed above, resources of money, materials and time eventually translate into curriculum, assessment, technology and support. The continuation of reform efforts requires that many of these resources be underwritten for a long time period to generate a systemic change culture in which learning, collegiality, and change are maintained and nurtured as natural components of the learning organization.

IMPLICATIONS FOR POLICY AND PRACTICE

Key Messages for Reformers

The cross-site analysis presented earlier was based on a systematic process of synthesis and interpretation. While this process has the advantage of keeping one close to the data, it tends to inhibit commentary of interest to many readers. Thus, at this point discussion of the case analyses is extended to address directly matters of interest to practitioner and policy-maker audiences and respond to questions often raised about what the cases tell people who want to pursue educational reform. Doing so is basically an extension of the interpretation already presented in the cross-site analysis, but it has additional commentary and on occasion is somewhat more speculative. These additional steps seem necessary to give the reader the benefit of months of immersion in the data from these case studies. At the same time, every attempt will be made to use language that alerts the reader to what is firmly grounded in the data and what statements are to varying degrees extrapolations from them.

As noted earlier, the schools in which these case studies were conducted were ordinary schools, not "hot-house" sites nurtured by heavy investment of researcher/expert time or the expenditure of unusually large amounts of additional funds. A central question about the reforms advocated by experts and national advisory groups is "how well they travel" in the "real world." The key messages presented below are a response to this central question.

1. **The complex and fundamental reforms advocated by the reformers are not easy to establish, but they are appropriate and worthy of pursuit**. While introduction of the reforms produces many dilemmas for teachers, requires a long and intensive effort, and seemingly is a continuing journey, these cases do not suggest that the reforms are inherently inappropriate. Indications are that student interest in the content increases, that students make more connections both between content and its applications and between content and other components of content, and that critical thinking is practiced to a greater degree.

2. **Time is a major dilemma for teachers in the reform context**. While teachers find that the time pressures let up as they become more successful in implementing their reforms, it is apparent that the time demands of the reforms are a dilemma for teachers. The major concern of teachers about the reforms was the time required for preparation and planning. The time required is not just for individual teacher planning; it is the time required working with fellow teachers to plan and coordinate the new venture. Additional time is required for formal learning, such as through inservice education classes, although the most important learning probably takes place in the context of the collaborative work with other teachers.

3. **Expect the reform process to extend over a long period of time**. The reforms cannot be hurried; they take years, not months. Anyone entering into a major reform endeavor should recognize from the outset that it will take a concerted effort over a long period of time. If one

reflects on the significant changes in roles, values and beliefs involved in the process, this required time is not surprising. The odds are very high that if someone in a reform context thinks that their reform is well established after two or three years, they either have an inadequate conception of the reforms advocated in the current reform literature (e.g., the NCTM or NRC Standards) or they do not have an accurate picture of the education taking place in their setting.

4. **Of central importance to the reforms are changed values and beliefs about the goals of instruction and the means of fostering this learning**. To reform education in the full sense demands more than the acquisition of new teaching strategies and techniques. It stretches well beyond the technical dimension to a reconsideration of the "why," "what," and "how" of education. This reconsideration is fostered when professionals are part of a "learning organization" (Senge, 1990) with a culture that values reflection, change, and collaboration. Changes in beliefs and values are not limited to the professionals at the site; reform demands that these new understandings be fostered among students and parents as well.

5. **Teacher learning is central to the process of reform, both in its own right and as a foundation for the required learning on the part of students and parents**. As noted above, the most important learning takes place in the context of collaborative work with other teachers, rather than in formal instructional settings. As a result, it may be valuable to think of the formal instruction as a means of fostering learning in the work context, i.e., setting the stage for the most desirable collaborative work setting. Staff development moneys should be used to address these matters collectively for school personnel--obviously including administrators as well as the teachers--in a manner that fosters a culture of change and openness to professional learning.

In many ways the conditions that are most favorable for fostering reform are the same as those for fostering teacher learning, since they go hand in hand. Means must be found for alleviating the time dilemma faced by teachers. Efforts must be made to establish the working conditions under which teacher have the time to plan together, reflect on the results of their work with students and challenge each other's conceptions of appropriate goals and content. Block scheduling, common planning periods for teaching teams, and released time for collaborative work are illustrative of such efforts.

Challenges to extant educational values and beliefs best occur in the context of the working world of schools. Putting such matters on the table for consideration in the context of addressing day-to-day teaching matters is not the same as directly challenging current school practices in the abstract for purposes of establishing the new Standards as the new norm of school practice. One of the cases provided an illustration of increased polarization and conflict among the teachers in a department when such matters of values and beliefs were "in your face" during inservice education. Individual reappraisal of such matters is most productive in the context of facing real teaching situations and collaborating with one's colleagues.

6. **Parent learning is an important part of the reform process**. When one recognizes the context in which teacher learning occurs and the time it requires, it is apparent that learning for parents is a major challenge. Where is the context and the big blocks of time required for such significant parent learning? In our cases, there were several instances of parental resistance substantially reduced by appropriate public relations efforts, largely through the direct work of teachers and administrators. In other instances such efforts did not solve the problems of parental resistance. One is left with the impression that the parents needed the opportunity to address fundamental issues in depth, an opportunity that is difficult to provide. The key to this parent learning may be through their children who are students in the reform setting. But student learning itself is a big issue.

7. **Students must be enabled to engage in new roles and perform new forms of student work**. Establishing new student roles and student work may be the true "bottom line" of reform. This shift is the key indicator of reform. Based on this indicator, many sites still had a long way to go. Students must become actively engaged in the process of working out these new roles. Just as new roles cannot simply and quickly be imposed on teachers, students must be drawn into a process in which they explore new roles and work, reflect on the results of this shift and learn what it meets for them to direct their own learning.

Throughout the case studies one sees a concern about grades on the part of students. This concern undoubtedly will influence the process of engaging students in a renegotiation of their role and work, although it is not clear from the cases how one would expect this influence to be exercised.

8. **Recognize that reform will hang in the balance for a long time**. Although not addressed directly in the above analysis, it may be apparent to the astute reader that most of these reforms to some degree or another are hanging in the balance. A critical breakdown in some aspect of the systemic support system that sustains them could result in the abandonment of the system in its totality. The departure of a key leader, structural changes that remove important mechanisms for collaboration, strong parental resistance, or the loss of another key foundational block could result in a direct decision to abandon the reform, or simply let it slide into neglect. Reform is hard work; it will not occur--or be sustained--without it. The dilemmas teacher face are real; appropriate support is needed for reforms to maintained on broad basis.

9. **At the same time, there is no going back on certain aspects of the reforms**. While noting that reform will hang in the balance for a long time, one must also recognize that individual teachers who have successfully initiated these reforms in their own classes generally claim that their teaching has been changed permanently and they will never go back to the "old ways." They say their role has changed and that it will not change back to what it was regardless of what happens with the reform project of which they are a part.

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Since teachers say that they would never go back to their regular way of teaching, the "bottom line" may be that many reforms will survive in at least some of a teacher's classes, regardless of what happens to the reforms in a programmatic sense. In this manner, many of the reforms could spread into common practice. When a teacher's beliefs and values regarding education have changed and this teacher has learned how to put these new perspectives into practice, this teacher has been permanently changed. The cases included examples of teachers who had moved to a new school with a conventional program who said this change had in fact occurred in them.

10. **A Systemic View is Essential**. An important theme found throughout the cross-site analysis is the need for a systemic perspective. It is obvious that these cases of successful reform are marked by attention to a multiplicity of factors--having technical, political, and cultural dimensions--in a manner that takes account of their interconnections. This multiplicity of factors is addressed simultaneously and in concert.

11. **Reform is an ongoing process**. Reform can be expected to continue in varying degrees in schools, departments and individuals. The process will go in fits and starts in various places, but the fact that teachers who have changed their role--and that of their students--convincingly claim they will not return to the old ways leads to considerable optimism that for the long run, one can expect a continuing overall movement toward reform.

IMPLICATIONS FOR NEEDED RESEARCH

Upon completion of a study, most researchers can identify many facets of their investigation that would benefit from even more research. Such is the case here; more understanding would be helpful with respect to educational goals, curriculum, instructional approaches, teacher roles, student roles, assessment, and the processes of educational change, among others. A few topics stand out, however, and will be addressed here. Generally, a few factors out of many potentially have an especially strong effect; they are the ones deserving of attention in this discussion of needed additional research.

Do the Research in the "Real World"

The results of this research strengthen the conviction that research in ordinary schools under everyday conditions is needed most. Research conducted under tightly controlled conditions, with the support of highly specialized educational expertise, and sufficient funding to insure the authenticity of the experimental variables is an important activity, but its usefulness is limited. The process of making desired changes under ordinary school conditions is not the same. Research is needed especially in the context of routine settings where all of the "real world" constraints apply. Such were the conditions under which this research was done; more is needed.

Approach the Research Systemically

Ay closely related idea is to approach the research systemicly. The educational reforms being promoted today are very complex. The context in which change is being sought is highly complex. The various processes of fostering change are decidedly complex. Under these circumstances it is essential to approach the research systemicly. Curriculum content, pedagogy, assessment, the social context of schooling, and much more, are all part of the picture and they interact. Unless the entire situation is approached systemicly, the prospects of understanding it are dim.

Assessment as an Example

Research on assessment serves as an example for both of the above points. Assessment, as a focal point of research studies, has received major attention in recent years. Much has been gained from this research, yet the picture of assessment that comes from these case studies is not what one would predict based on the rhetoric of the educational reform literature and the implications drawn from the ongoing assessment research. As noted above, new approaches to classroom assessment are relatively low on the agenda of many teachers working towaru educational reform. A lot of other curricular and instructional matters seem to demand attention first. And when it comes to large-scale assessment, teachers generally do not look to it as a promising lever for reform; they just hope it improves enough to not cause them unduly great problems. Assessment problems look different in the "real world" of educational reform and

studies of assessment must be approached systemicly in that context if its true role and impact is to be understood. Separate--i.e., non-systemic--studies of assessment are not a plausible entry point for studies of implementing the NCTM Curriculum and Evaluation Standards for School Mathematics or the NRC National Standards for Science Education in ordinary schools.

Focus on Student Roles and Student Work

A critical finding of the cross-site analysis is that changes in the roles of students and in the nature of the work they do is at the heart of educational reform. In this sense, the results of the research substantiate the recommendations of the reformers. Without the desired changes in student role and work, true reform does not occur. On the other hand, appropriate changes in this regard have a high probability of insuring the reform.

A related finding of the research is that in the cases studied, a failure to bring about the desired level of change in this arena was almost universal. Thus, the highest priority for future research has to be given to this topic. It is an area that has been researched very little in the sense that it is being advocated here, namely extending the ideas of constructivist learning to give students a lead role in shaping these changes. Elaboration of the type of research needed has been published by other researchers since the cross-site analysis reported here was completed (Corbett & Wilson, 1995).

Teacher Learning Needs Major Attention

Changes in students' roles and work will come about through the work of teachers in classrooms. Thus, the role of teachers needs major attention to understand better just how they can foster these student changes. The results of the cross-site analysis emphasize that teacher learning is central to educational reform and that (1) it apparently takes place most readily in collaborative work contexts, and (2) hinges upon changes in values and beliefs. The pedagogy dimensions of the new standards for science and mathematics are central to these concerns.

Research is needed to understand more fully the collaboration that must be developed, especially in the day-to-day work context, but also through inservice education and through conferences and networks. More understanding is needed of learning organizations--in terms of both teachers and students--and how it is related to values and beliefs, both individually and collectively.

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